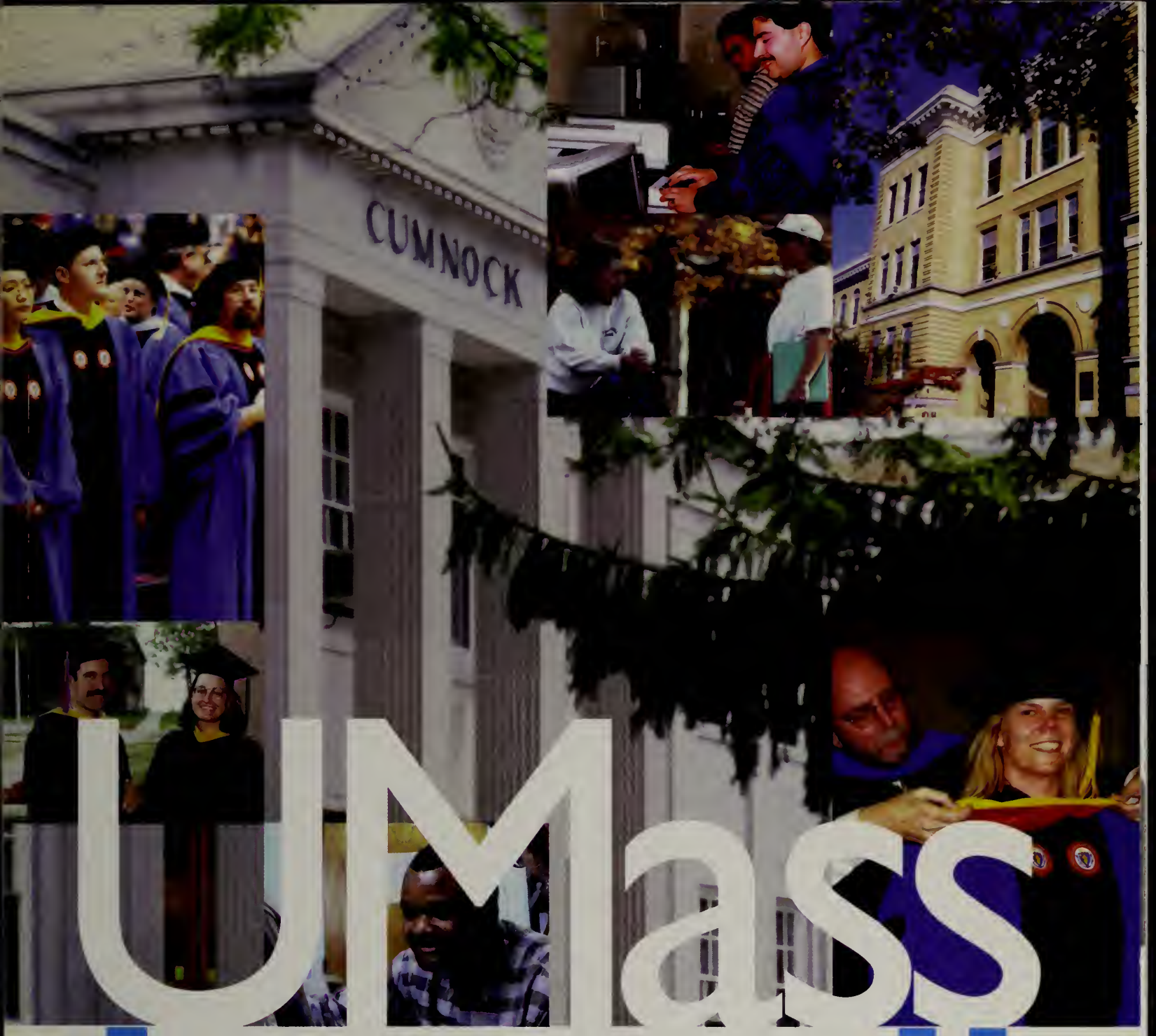

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'99-'02

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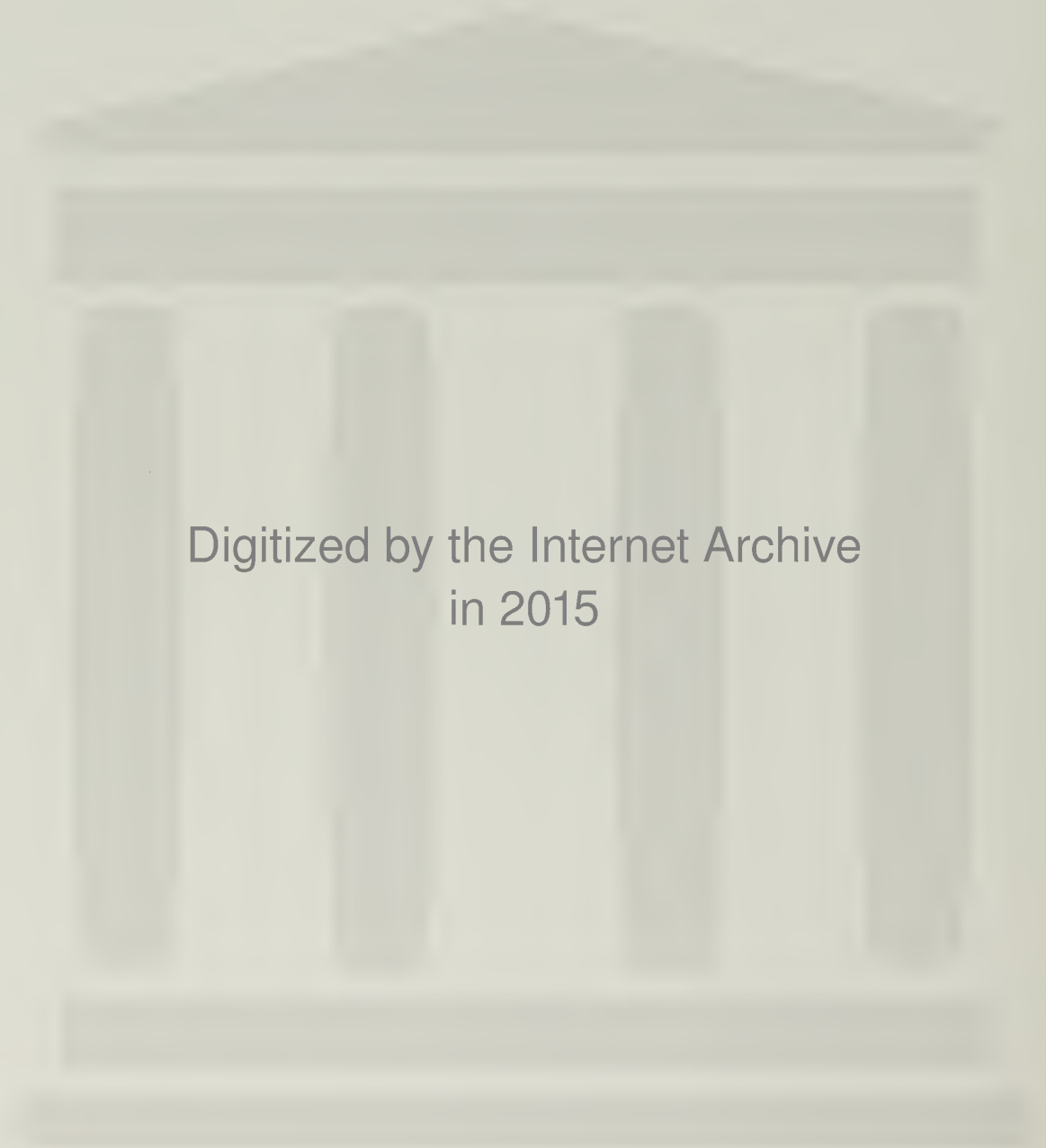

University of Massachusetts Lowell

1999-2002

Graduate School Catalog

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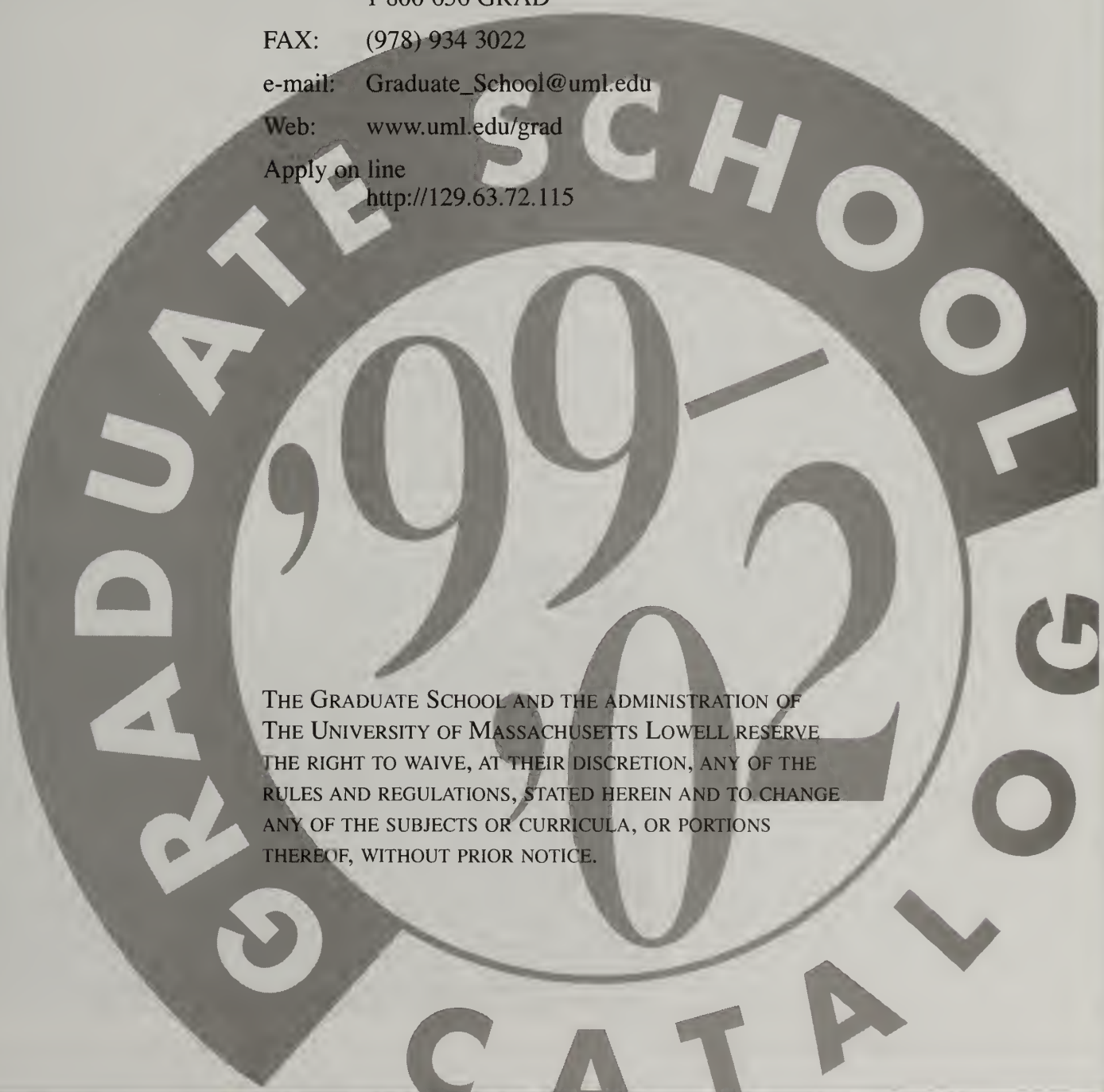


IN MEMORY OF

Natalie A. McCluskey
1999
Co-worker and friend

About the UNIVERSITY

FINANCIAL INFORMATION

ADMISSIONS

REQUIREMENTS FOR DEGREE CONFERRAL

GENERAL REGULATIONS

UMass Lowell

UNIVERSITY OF MASSACHUSETTS LOWELL
Graduate School

The University of Massachusetts Lowell is an Equal Opportunity/ Affirmative Action University and does not discriminate in employment or access to programs or services on the basis of race, sex, sexual orientation, color, national origin, religion, handicap or veteran's status and is in compliance with Title IX of the Education Amendments of 1972 and Section 504 of the Rehabilitation Act of 1973, and the Americans With Disabilities Act, 1990. Any inquiries and/or grievances may be referred to the Affirmative Action Officer, the Title IX Coordinator, the Disabilities Coordinator and/or to the Director, Office for Civil Rights, U.S. Department of Health and Human Services, Washington, DC.

This catalog was prepared well in advance of its effective date; as a result, it is possible that the course descriptions may vary to some extent from actual course content due to advancements in the discipline or for other reasons. Therefore, the course descriptions that are given are provided for information purposes rather than as a contractual obligation.

The Graduate School and the University of Massachusetts Lowell are not responsible for statements or agreements entered into or made by any University official or faculty member which do not conform to the rules and regulations in this catalog and/or which have not been approved by the Graduate Dean.

A member of the five campus system of the University of Massachusetts created by the Commonwealth of Massachusetts Legislature in July, 1991.

ACCREDITATION AND PROFESSIONAL MEMBERSHIPS

The University of Massachusetts Lowell is accredited by the Commission on Institutions of Higher Education and New England Association of Schools and Colleges. Professional programs are also individually accredited by the following national associations which evaluate at the graduate level:

American Assembly of Collegiate Schools of Business
National Association of Schools of Music
National Council for the Accreditation of Teacher Education
(Elementary, Secondary, and Music Education)
National League for Nursing

The University of Massachusetts Lowell is also a member in good standing of the following associations of higher education:

Accreditation Board for Engineering and Technology
American Assembly of Collegiate Schools of Business
American Association of Colleges for Teacher Education
American Association of Colleges of Nursing
American Chemical Society
American Council on Education
American Physical Therapy Association
American Society for Engineering Education
American Society of Allied Health Professions
Association for Gerontology in Higher Education
Association for State Colleges and Universities
Association of University Programs in Health Administration
College Entrance Examination Board
Council of Colleges of Arts and Sciences
Council of Graduate Schools in the United States
Interstate Certification Compact
Massachusetts Association of Colleges of Nursing
National Association for Industrial Technology
National Association of Summer Sessions
National Association of State Directors of Teacher Education and Certification
National League for Nursing Council of Baccalaureate and Higher Degree Programs
National University Continuing Education Association
New England Board of Higher Education

REPORTING CORRECT ADDRESS

It is important that students report address changes on special forms provided for that purpose in the Graduate School Office. All grades, correspondence, etc., will be sent to the latest mailing address on file.

PROGRAMS OFFERED

The University of Massachusetts Lowell Graduate School offers graduate programs in the following areas:

Doctor of Philosophy (Ph.D.)

Chemistry - (options: Environmental Studies, and Biochemistry)
Nursing - (option: Health Promotion)
Physics - (options: Energy Engineering, Applied Mechanics, and Radiological Sciences)
Polymer Science - (option: Polymer Science/Plastics Engineering)

Doctor of Science (Sc.D.)

Computer Science - (option: Computational Math)
Work Environment - (options: Industrial Hygiene, Occupational, Ergonomics, Epidemiology, Work Environment Policy, Cleaner Production and Pollution Prevention)

Doctor of Education (Ed.D.)

Mathematics and Science Education
Leadership in Schooling
Language Arts and Literacy

Doctor of Engineering (D.Eng.)

Electrical Engineering
Mechanical Engineering - (Chemical/Civil Interdisciplinary) (options: Thermal/Fluid/Transport Processes Solid Mechanics/Materials/Structures Dynamics/Systems/Controls Energy/Environmental Design/Manufacturing)
Plastics Engineering

Certificate of Advanced Graduate Study (C.A.G.S.)

Administration, Planning and Policy, Curriculum and Instruction, Reading and Language

Master of Arts (M.A.)

Community and Social Psychology
Criminal Justice
Economic and Social Development of Regions

Master of Science (M.S.)

Biological Sciences (option: Biotechnology)
Chemistry
Clinical Laboratory Sciences
Computer Science
Environmental Studies; concentration: Atmospheric Sciences
Health Services Administration
Mathematics - (options: Applied Mathematics, Mathematics for Teachers, Scientific Computing, and Statistics and Operations Research)
Nursing - (options: Gerontological, Family Health, Adult Psychiatric/Mental Health)
Physics - (option: Optics)
Physical Therapy - Entry level (option: Advanced Practice)
Radiological Sciences and Protection
Work Environment - (options: Industrial Hygiene, Occupational Ergonomics, Epidemiology, Work Environment Policy, Cleaner Production and Pollution Prevention)

Master of Science in Engineering (M.S. Eng.)

Chemical Engineering
Civil Engineering (options: Geotechnical, Structural, Transportation, Environmental and GeoEnvironmental)
Computer Engineering
Electrical Engineering (option: Opto-Electronics)
Energy Engineering (options: Solar, Nuclear)
Materials Engineering (option: Electronic and Photonic Materials)
Mechanical Engineering
Plastics Engineering (options: Coatings and Adhesives, and Fiber/Composites)

Master of Education (M. Ed.)

Curriculum and Instruction - (options: English as a Second Language, and Teacher Certification)
Educational Administration
Reading and Language

Master of Music (M.M.)

Music Education - (option: Teacher Certification)
Performance (options: Applied Performance, Conducting)

Master of Business Administration (M.B.A.)

Master of Management Science in Manufacturing (M.M.S.)

GRADUATE CERTIFICATE PROGRAMS

Each certificate is comprised of four courses designed to provide specific knowledge and expertise vital to today's changing and complex needs in the work place. In most cases courses may be applied toward a degree program.

Application Process

Individuals must complete a simplified application and provide a photocopy of their undergraduate transcript indicating that a baccalaureate degree has been awarded. There is no application fee and GRE's are not required.

Requirements to Complete a Graduate Certificate

The four courses must be completed within a five year period with a minimum 3.0 grade point average and with not more than one course with a grade of BC or C.

Biomedical, Health, Social Sciences

Biotechnology & Bioprocessing
Chemistry
Clinical Pathology
Criminal Justice Leadership Policy & Development
Domestic Violence Prevention
Economic & Social Development of Regions
Health Services Administration
Job Stress & Healthy Job Redesign
Medical Physics
Radiological Health Physics & General Work Environment Protection

Computers, Communications, Information Systems

Human-Computer Interaction
Telecommunications

Environmental

Environmental Risk Assessment
Groundwater Contamination & Modeling
Identification & Control of Ergonomic Hazards
Radioactive Waste Management

Engineering, Manufacturing, Management

Commercialization of Science & Technology
Communications Engineering
Energy Conversion
Foundations of Business
Manufacturing Engineering
Materials Sciences & Engineering
Photonics Opto-Electronic Devices
Stochastic Systems
VLSI and Microelectronics

For more information, call or write:
The Graduate School
UMass Lowell
One University Avenue
Lowell, MA 01854

☎:(978) 934 2381
FAX: (978) 934 3010
TTY: (978) 934 2367
(800) 656-GRAD
e-mail: Graduate_School@uml.edu
Web:www.uml.edu/grad

SUMMARY OF MASTER'S DEGREE CREDIT REQUIREMENTS

COLLEGE PROGRAM REQUIREMENTS	COURSE/SEMINAR CREDITS	THESIS/PROJECT CREDITS	TOTAL CREDITS
COLLEGE OF ARTS AND SCIENCES			
BIOLOGICAL SCIENCES			
THESIS	18-24	6-12	30
PROJECT	24-27	3-6	30
NON-THESIS	30	0	30
CHEMISTRY			
THESIS	18	12	30
COMPUTER SCIENCE			
THESIS	24	6	30
NON-THESIS	30	0	30
CRIMINAL JUSTICE			
THESIS	27	6	33
NON-THESIS	33	0	33
ECONOMIC & SOCIAL DEV.			
THESIS	27	6	33
PROJECT	27	3	30
MATHEMATICS			
APPLIED	30	0	30
SCIENTIFIC COMPUTING	30	0	30
FOR TEACHERS	30	0	30
STAT. & OP. RES	30	0	30
MUSIC EDUCATION			
THESIS	27	3	30
TEACHER CERT.	28	2	30
NON-THESIS	30	0	30
MUSIC PERFORMANCE			
NON-THESIS	33	0	33
PHYSICS			
THESIS	18-24	6-12	30
PROJECT	27	3	30
PSYCHOLOGY			
THESIS	30	6	36
PROJECT	33	3	36
RADIOLOGICAL SCIENCES			
THESIS	24	6-9	30
PROJECT	27	3	30
GRADUATE SCHOOL OF EDUCATION			
CAGS	30	0	30 (Beyond master's degree)
CURRICULUM & INSTRUCTION			
ENGLISH AS A SECOND LANGUAGE	30	0	30
TEACHER CERTIFICATION	30	0	30
EDUCATIONAL ADMINISTRATION			
NON-THESIS	30	0	30
PROJECT	24	6	30
READING & LANGUAGE			
NON-THESIS	30	0	30

COLLEGE PROGRAM REQUIREMENTS	COURSE/SEMINAR CREDITS	THESIS/PROJECT CREDITS	TOTAL CREDITS
COLLEGE OF ENGINEERING			
CHEMICAL			
THESIS	26	6	32
PROJECT	29	3	32
CIVIL			
THESIS	24	6	30
NON-THESIS	30	0	30
PROJECT	27	3	30
COMPUTER			
THESIS	24	6	30
NON-THESIS	33	0	33
PROJECT	30	3	33
ELECTRICAL			
THESIS	24	6	30
NON-THESIS	33	0	33
PROJECT	30	3	33
ENERGY			
THESIS	24	6	30
PROJECT	27	3	30
ENVIRONMENTAL STUDIES			
THESIS	24	6	30
NON-THESIS	30	0	30
ATMOSPHERIC SCIENCES			
THESIS	24	6	30
MATERIALS SCIENCE & ENGINEERING			
THESIS	26	6	32
PROJECT	29	3	32
MECHANICAL			
THESIS	24	9	33
PROJECT	27	6	33
NON-THESIS	33	0	33
PLASTICS			
THESIS	24	6	30
WORK ENVIRONMENT			
THESIS	39	6	45
PROJECT	42	3	45
COLLEGE OF HEALTH PROFESSIONS			
ADULT PSYCHIATRIC/MENTAL HEALTH NURSING			
THESIS/PROJECT	39	3	42
CLINICAL LABORATORY SCIENCES			
THESIS/PROJECT	22-26	4-8	30
FAMILY HEALTH NURSING			
THESIS/PROJECT	39	3	42
GERONTOLOGICAL NURSING			
THESIS/PROJECT	39	3	42
HEALTH SERVICES ADMINISTRATION			
THESIS/PROJECT	39	3	42
PHYSICAL THERAPY			
ENTRY LEVEL	77	0	77
ADVANCED PRACTICE	30	0	30

COLLEGE PROGRAM REQUIREMENTS	COURSE/SEMINAR CREDITS	THESIS/PROJECT CREDITS	TOTAL CREDITS
COLLEGE OF MANAGEMENT			
BUSINESS ADMINISTRATION			
NON-THESIS	42	0	42
M.M.S. MANUFACTURING			
NON-THESIS	33	0	33
GRADUATE CERTIFICATES	12	0	12 (Beyond bachelor's degree)

SUMMARY OF DOCTORAL DEGREE CREDIT REQUIREMENTS

COLLEGE OF ARTS & SCIENCES			
BIOCHEMISTRY (Ph.D.)	27	18	45
CHEMISTRY (Ph.D.)	27	18	45
COMPUTER SCI. (Sc.D.)	18	24	42
COMPUT. MATH OPTION (Sc.D.)	18	24	42 (Beyond master's degree)
ENVIRONMENTAL STUDIES (Ph.D.)	39	18	57
PHYSICS (Ph.D.)	36-45	15-24	60
POLYMER SCI. (Ph.D.)	27	18	45
GRADUATE SCHOOL OF EDUCATION			
Ed.D.			
MATHEMATICS AND SCIENCE EDUCATION	51	9	60
LEADERSHIP IN SCHOOLING	51	9	60
LANGUAGE ARTS AND LITERACY	51	9	60 (All Beyond master's degree)
COLLEGE OF ENGINEERING			
ELECTRICAL (D.Eng.)	42	21	63
MECHANICAL (D.Eng.)	42	21	63
***CIVIL**	42	21	63
***CHEMICAL**	42	21	63
***INTERDISCIPLINARY OPTIONS OFFERED THROUGH MECHANICAL ENGINEERING**			
PLASTICS (D.Eng.)	42	21	63
WORK ENV. (Sc.D.)	6-18	12-24	30 (Beyond master's degree)
COLLEGE OF HEALTH PROFESSIONS			
NURSING (Ph.D.)	48	12	60 (Beyond master's degree)

UNIVERSITY PROFILE

History

Lowell Normal School (later Lowell State College) and Lowell Textile Institute (later Lowell Technological Institute), the "parents" of the University of Massachusetts Lowell, were established in the last decade of the 19th century as single-purpose institutions, charged with providing instruction in those theories and practical arts which were most suitable to the teaching profession and the textile industry. Clearly, their institutional missions were to contribute to the economic and educational vitality of the region.

When those two institutions were merged into the University of Lowell in 1973, the new University was also given a mission to support the economic and social development of the region. The legislation which created the University of Lowell directed the University to "provide, without discrimination, educational programs, research, extension, and continuing education services in the liberal arts, in engineering and the sciences, and in the professions."

In July 1991, the legislature of the Commonwealth of Massachusetts with the strong endorsement of the governor, created the five campus system of the University of Massachusetts which incorporated the University of Lowell. The other four campuses included in this merger were Amherst, Boston, Dartmouth and Worcester. Currently, the University of Massachusetts is the largest institute of higher education in New England with approximately 57,000 students, over 4,000 faculty members and awards over 10,000 degrees/year.

As the technologically - oriented campus, the University of Massachusetts Lowell has as its mission to "preserve, discover, integrate and transmit knowledge; and to serve as a cultural, civic, intellectual and economic resource to its constituents in the region, the Commonwealth and the nation." Focusing on three degree clusters:

1) engineering/management/science; 2) education; and 3) health, the Lowell campus has been charged with spearheading efforts to support the development of a sustainable vigorous regional industrial economy.

As part of this initiative, the University of Massachusetts Lowell established in 1993 the Council for Industrial Development consisting of the following research centers and institutes which offer cutting-edge, state-of-the-art research and training opportunities for graduate students:

Advanced Biomaterials
Advanced Computation & Telecommunications
Advanced Electronics Technology
Advanced Materials
Atmospheric Research
Biodegradable Polymer Research
BioProcess Development Center
Cardiovascular Disease Control
Demonstration School
Electric Car and Energy Conversion
Electromagnetic Materials and Optical Systems
Environmental Engineering & Science Technologies
Environmentally Appropriate Materials
Ergonomics Institute
Family, Work, and Community
Field Services and Studies
Health Promotion
Industrial Competitiveness
Intelligent Biomaterials
Photonics and Optoelectronics
Plastics Innovation
Productivity Enhancement
Radiation Laboratory
Recording Arts, Technology and Industry
Submillimeter-Wave Technology Laboratory
Sustainable Energy
Sustainable Production
Toxics Use Reduction Institute
Tropical Diseases and Biomedicine
Tsongas Industrial History
Visualization and Perception Research
Women in Workplace Research Center

GRADUATE STUDENTS, FACULTY AND ACADEMIC PROGRAMS

The University of Massachusetts Lowell's graduate students account for 2,800 of the over 12,000 students enrolled in both state-supported and Continuing Education programs. There are 450 full-time faculty members. Lowells' distinguished faculty are internationally known for their research and extensive publications, a number have received Fulbright and other prestigious awards, and as a group they obtained $21 million in research grants and contracts in FY1999. The Graduate School offers diversified graduate programs in the fields of business administration/management/manufacturing, education, engineering, health professions, music, science, criminal justice, psychology, and regional economic & social development.

A CHALLENGE TO THE UNIVERSITY OF MASSACHUSETTS LOWELL

Just as the city of Lowell with its innovative textile manufacturing industry served as the birthplace of the first industrial revolution in America more than 150 years ago, the University of Massachusetts Lowell has been challenged by its Board of Trustees to act as the driving force behind a new industrial/technological revolution which will serve as a demonstration model for national economic development through continuous innovation. As an integral component of this bold new initiative, the University of Massachusetts Lowell's charge is:

1) to provide educational and research programs designed to support and enhance the development of a sustainable, vigorous industrial economic sector;

2) to focus on an integrated strategy in which the academic disciplines of engineering, management, arts and science, education, and health are applied to the pursuit of a robust, self-renewing industrial economy.

Mission of the Graduate School

The mission of the Graduate School at the University of Massachusetts Lowell is to provide a fertile and stimulating environment for teaching, learning, research, dissemination of professional skills, and to promote the pursuit of knowledge. To this end, the Graduate School encourages the assemblage of scholars, scientists, and artists under whose direction graduate students can pursue advanced studies and carry out research activities. The quality of the graduate faculty involved in these programs is the most important factor contributing to excellence in teaching and scholarly research.

The central purpose of the University is to enhance the quality of life in our society through knowledge. The role of the Graduate School in this overall objective is to educate individuals with superior ability, and to develop in them the competence and motivation which will enable them to realize their personal and community potential. Finally, because it plays a key role in academic leadership at a publicly-supported institution of higher education, the Graduate School recognizes its responsibility to develop the

technical expertise of the region and to advance the frontiers of knowledge through research.

Location

In the heart of the birthplace of America's Industrial Revolution, the city of Lowell Massachusetts is 25 miles from Boston, and home to the first urban National Historic Park in the United States. The Merrimack River runs through this city of 103,000 which hosts professional baseball and hockey adjacent to the University's campus. Access to Boston and Worcester is easy via car or commuter train. The lakes and mountains of New Hampshire, Vermont and Maine, as well as the shores and beaches of the Atlantic Ocean and Cape Cod, are short driving distances away. The two major campuses lie on opposite sides of the Merrimack River, the power source which gave rise to America's first industrial city. The North Campus is the primary location for the Sciences, Education, Engineering, and Management and is a short distance across the river from the new state of the art student recreation center, a new minor league baseball stadium, the Tsongas Arena, home of college and professional hockey, and the scenic riverwalk. The recreation facility is the center for student campus life, including many activities open to graduate students. The South Campus is situated on a bend in the Merrimack River approximately one mile upstream from the North Campus and occupies an elevated site midway between the mouths of the historic Middlesex and Pawtucket Canals. The College of Health Professions is located on the South Campus as are most programs in the liberal arts. The campuses are easily accessible by car from US Route 3 and Interstate 495, by train from Boston (Massachusetts Bay Transportation Authority), and by local and interstate bus lines (Massachusetts Bay Transportation Authority, Continental, and Vermont Transit).

In addition to being the home of the University of Massachusetts Lowell, Lowell is a city rich in heritage. Due to its prime location on the Merrimack River, it became the first great industrial city in the United States. Different immigrant groups migrated to Lowell to work in the mills that were built along the river. Today, the descendants of these varied ethnic groups, plus many new arrivals, make up much of Lowell's population. The city is the site of an Urban State and National Park, illustrating Lowell's industrial and multi-ethnic history.

UNIVERSITY LIBRARIES

The University libraries consist of the Alumni/Lydon Library, O'Leary Library, the Center for Lowell History and the Education Curriculum Center. The library system is fully computerized with extensive databases, accessible on or off campus, and is linked to other major libraries through consortia arrangements. UMass Lowell has the most fully developed electronic library in the Commonwealth of Massachusetts.

Media Centers are located on both the North and South campuses.

OFF-CAMPUS GRADUATE COURSES

For the convenience of working adults, the Graduate School offers graduate courses and programs off-campus in the region. Selected programs and courses are hosted by companies and community sites in the Fall, Spring, and Summer, and have included the areas of computer science, clinical laboratory science, electrical engineering, civil engineering, plastics engineering, criminal justice, management, and work environment. Detailed information and current course/site listings are accessible at http://www.uml.edu/grad/off campus.html or by calling the Graduate School.

Some of the "satellite campus" locations and companies choosing UMass Lowell to meet their graduate educational needs have included: Cadence Design Systems (Chelmsford), NYPRO Plastics (Clinton), McCormack Building/ Government Center (Boston), GTE (Waltham), Raytheon (Andover), U.S. Army Research Center (Natick), Gillette (Boston), BIC Corp. (Milford,CT), Hewlett-Packard (Andover), Northern Essex Community College (Haverhill), Bunker Hill Community College (Boston), Volpe DOT Transportation Center (Cambridge), Polaroid (Waltham), Westford Academy (Westford), Lahey Clinic (Burlington), Hanscom Air Force Base (Bedford).

Industrial-community relations are nurtured and enhanced through research collaborations, technology exchange, student internships, and advisory boards. Department faculty members routinely interact with industry, business, community groups and government agencies.

Individuals and companies interested in learning more about hosting on-site of graduate courses should contact: James Magarian, Director of Corporate and Community Graduate Relations at 978-934-3626 [jmagaria@cs.uml.edu].

RESOURCES

Computer Resources

The University of Massachusetts Lowell provides students and faculty with one of the largest, most sophisticated academic computing environments in the United States. Computer accounts are issued to all students. The University has numerous workstations, PC's, and terminals connected to multiple servers via a state-of-the art network infrastructure comprised of ATM and 10/100 megabit Ethernet switching technology. Multimedia labs, distance learning classrooms, and an extensive cybered program are available.

Research Foundation

The Research Foundation was established in 1950 as a not-for-profit organization which operates with income derived from research funded by private industry, foundations, and government agencies. The Foundation contains major support facilities for faculty and student research projects, and provides a mechanism for the administration and fiscal management of all academic grants and contracts for research and training.

As part of its close cooperation with the University, the Research Foundation employs both graduate and undergraduate students from the University on a part-time basis. These students gain practical experience which often becomes part of an advanced degree program.

The Research Foundation also houses Commercial Ventures and Intellectual Property and the Institute for Massachusetts Partnering and Commercializing of Technology which oversee licensing technologies and the development of joint venture products.

Continuing Studies and Corporate Education

Opportunities for graduate study are provided in two summer sessions offering courses in many of the degree programs, summer day workshops, and special projects.

STUDENT SERVICES

Housing

Unmarried graduate students may choose to live in on-campus housing arrangements. This housing option is in a traditional residence hall where graduate students reside in single rooms with other graduate students or undergraduate students who are at least 23 years of age. If space is available, graduate students may also choose to live in any of our traditional or suite-style halls with other graduate or undergraduate students. These buildings typically have traditional aged (18-22 years) undergraduates residing in them. Residence halls have 2-4 bedrooms (double occupancy), 1-2 bathrooms, and a living room area. All on-campus housing is by academic year.

Married graduate students and their families are offered housing at the East Meadow Lane apartments. These apartments are studio, one, and two bedroom apartments; all are unfurnished, except for studio apartments. To apply for this housing option, please call the Office of Residence Life (978-934-2112).

Health Services

The University Student Health Services Office is open 8:00 am to 4:30 pm, Monday through Friday. It is located in McGauvran Hall, South Campus (978-934-4991). All students with a completed health record on file at the Student Health Services Office are eligible for treatment. Services include first aid, care of minor illnesses, monitoring of chronic illness, and health counseling. Services are provided by a physician, nurse practitioner, or registered nurse with referrals to and consultation with specialists, as appropriate.

Medications prescribed by the Health Service must be filled at a pharmacy of the student's choice and at the student's expense.

Most laboratory tests can be performed at the Health Services Office. All other tests and X-rays are referred to area laboratories, and the student is responsible for fees incurred.

When the Health Services Office is closed, medical service may be obtained at one of the two area hospitals or any local walk-in-clinic.

Proof of Immunization

The Commonwealth of Massachusetts requires that all full-time graduate students (9 or more credits) must be immunized against measles, mumps, rubella, tetanus and diphtheria. In addition, all students in the College of Health Professions and all international students, regardless of enrollment status, must show proof of immunization. Students will not be permitted to register for courses at the University unless proof of immunization has been sent directly to: Ms. Nancy Quattrocchi, Director of Health Services, University of Massachusetts, Lowell, MA 01854 (978-934-4991).

Graduate Student Association

The purpose of the Graduate Student Association (GSA) is to enhance the academic, social, and economic advancement of all graduate students, to represent the graduate student body in university affairs, and to establish closer interdepartmental relations among graduate students, faculty, and the administration. In addition, the GSA seeks to promote the common interests and better communication among graduate students and with other components of the university community. All graduate students registered for courses are considered members of the GSA.

FINANCIAL INFORMATION

University-related costs include tuition and mandatory fees. Please contact the Business Office, Accounts Receivable, at 978-934-3570, for more information.

New England Regional Student Program

Massachusetts and the University participate in a reciprocal program in which qualified and legal residents of other New England states may attend graduate school at the University of Massachusetts Lowell and pay 150% of the Massachusetts in-state tuition charges. (All other applicable fees apply.) Applicants are considered for unique and distinctive graduate level studies not available in their home state university system. Full details regarding eligible programs are available from the New England Board of Higher Education, 45 Temple Place, Boston, Massachusetts 02111 (617-357-9620) or at the University Massachusetts of Lowell Graduate School office.

Health Insurance

Mandatory on-campus (accident) insurance is charged to all graduate students. Matriculated graduate students enrolled in 9 or more credit hours will be charged for health insurance as required by state law. Graduate students may waive student health insurance charges if they maintain comparable insurance coverage and complete an insurance waiver form by the required deadline. Forms are available in the Graduate School Office and Accounts Receivable Office, Dugan Hall, South Campus. Family health insurance plans are also available with options for coverage of spouses and/or spouses and dependent children. Please contact the Accounts Receivable Office for further information (978 934-3570).

Veterans

The University of Massachusetts Lowell is approved for Veterans Administration benefits. Eligible veterans should obtain the necessary application from the Veterans Administration or Graduate School and present it to the Graduate School office at or before registration.

All recipients of veterans' benefits are required to certify attendance each month by signing a sheet available outside of the Graduate School office. The Veterans Administration will receive names of those students who fail to sign this attendance roster.

Senior Citizens

Citizens of Massachusetts, age 60 and over, are entitled to free tuition at the University on a space available basis. Positive identification and proof of age must be presented. Applicable fees and costs of instructional materials (books, etc.) are not covered by this waiver. In addition, tuition for short-term intensive workshops or seminars is not covered by this waiver. Senior citizens who are admitted as matriculated students must satisfy established admission requirements for programs.

RESIDENCY CLASSIFICATION

Rules for Determination of Domicile

University tuition rates are established on the basis of official state residency as determined by a student's true "domicile." "Domicile" is defined as a person's true, fixed and permanent home and place of habitation where he or she intends to remain permanently or for an indefinite time.

Massachusetts residency for tuition purposes is not acquired by mere physical

presence in Massachusetts while a person is carrying on a course of study at the University.

A student's residency status is based on a determination of one's domicile at the time of entry or re-entry to the University. Residency forms should normally be submitted when one accepts admission into the Graduate School. A student may apply to be reclassified at any time and must provide detailed documentation to support the claim that he or she met the requirements for Massachusetts residency for tuition purposes at the time of his or her entry as a student. One notable exception is made for students who marry Massachusetts residents while enrolled in a course of studies. The complete set of rules are attached to the application for reclassification. These applications are available from the Residency Officer, located in the Office of the Vice Chancellor for Administration and Finance in Dugan Hall, South Campus (978-934-3577).

FINANCIAL ASSISTANCE

Financial Aid

Financial need is determined after the student has completed a Free Application for Federal Student Aid, available from the Financial Aid Office (978-934-4220) or www.fafsa.ed.gov The major source of financial aid recommended for students is the William D. Ford Federal Direct Student Loan Program. This program allows the student to borrow up to $8,500 per year at a low variable interest rate. Needy students will have their loan subsidized by the federal government and will begin repayment after dropping below 6 credits/semester. Students who do not demonstrate financial need can borrow an Unsubsidized Federal Student Loan. The student can choose to pay the interest while in school or capitalize the interest. The principal on this loan is deferred until the student terminates enrollment or drops below 6 credits per semester. First time loan borrowers at UML are required to attend an entrance interview session prior to loan disbursement.

Graduate students may also apply for TERI, Fleet First, or Plato loans. Information regarding interest rates, repayment schedules, and eligibility for these loans may be obtained from the Financial Aid Office or a participating lending institution.

In addition, UML participates in: Federal Perkins Student Loan and the College Work Study Program. Students who demonstrate full financial need will be considered for these programs. For more information, students should call or write the Office of Financial Aid in the McGauvran Student Union Building, South Campus (978-934-4220).

Graduate nursing students are eligible for the Federal Professional Nurse Traineeship Grant Program. For more information contact the Department of Nursing.

ASSISTANTSHIPS

Teaching Assistantships

A limited number of teaching assistantships are available for qualified full-time students. These positions are assigned by the student's department and are subject to the agreement between UMass Lowell and UAW/Graduate Employees Organization. Therefore, all requests for teaching assistantships should be directed to the graduate coordinator or chairperson in a particular program. A student who signs a teaching assistantship contract after April 15th is legally bound to honor this agreement and may not accept an offer from another institution, in accordance with the 1988 Council of Graduate Schools resolution governing this matter.

Students interested in receiving an assistantship should file their applications for admission to a degree program as early as possible, checking the appropriate box on the application form. A student who is to receive an assistantship will be notified and sent a contract directly by the department. Reappointments in succeeding years are contingent upon satisfactory performance of duties as well as academic achievement. Master's degree candidates may hold an assistantship for a maximum of two years and doctoral candidates for a maximum of four years.

To ensure that teaching assistantships are awarded to the most qualified individuals, the Graduate School has established the following requirements:

1. No teaching/research assistantship may be awarded to a graduate student with incompletes, F's, or U's on his or her transcript.

2. No teaching/research assistantship may be awarded to a graduate student with a cumulative grade point average under 3.0 on the official transcript.

3. No university-funded teaching/research assistantship may be awarded to a master's degree candidate if he or she has completed the total number of credits required for his or her program.

4. Level 3 teaching/research assistantships may only be awarded to graduate students who have reached doctoral candidacy (i.e. completed all course work, oral/written and language examinations) and are enrolled in dissertation research.

Research Assistantships Funded by Principal Investigators

Research assistantships are available through special arrangements with individual research advisors. Individuals interested in research assistantships should contact departmental faculty members concerning the availability of this form of financial aid. Students who receive teaching or research assistantships must be matriculated and full-time (minimum of 9 credits/semester).

MEFA

Low interest student loans are also available for citizens of Massachusetts, Argentina, Brazil, and Canada through the Massachusetts Educational Financing Authority (MEFA). For more information: 1-800-842-1531, http://www.mefa.org.

Graduate Student Assistantships

A limited number of student assistantships are available in the departments. Students in this category are paid an hourly rate and are obligated to pay their own tuition and fees.

All queries concerning assistantships should be directed to the graduate coordinator in the student's department.

Payment of Bills

Graduate students will be permitted to attend classes and to utilize University facilities only after they have cleared all their financial obligations to the University. Financial obligations include indebtedness for library and parking fines, rental payments, and repayment of emergency loans. All bills are payable in advance by check or money order and are due as specified on the student invoice. Major credit cards are also accepted. All payments of fees and tuition should be made payable directly to the University of Massachusetts Lowell. A student in debt to the University at the end of any semester or summer session is not permitted to register again at the University

until his or her indebtedness has been discharged. In addition, student transcripts and diplomas will not be released unless all indebtedness has been discharged.

Overdue Accounts

Should it be necessary to utilize the services of a collection agency or attorney for an overdue student account, the student will be liable for any and all legal fees, commissions, and associated service charges.

Payment Plans

The University of Massachusetts Lowell offers a low-cost, interest-free payment option administered by Academic Management Services (AMS). This plan allows students to budget the annual cost of tuition and fees over a ten month period. Please call AMS directly at 1-800-635-0120 or stop by the Business Office, Dugan Hall, South Campus for more information.

University Charges

University-related costs include tuition and mandatory fees. Please contact the Business Office, Accounts Receivable, at 978-934-3570 for more information.

ADMISSIONS

Admission Requirements

The general requirements for admission to graduate study at the University are listed below.

1. The applicant must show official evidence of having earned a baccalaureate degree or its U.S. equivalent from an accredited college or university. If an international transcript does not adequately demonstrate that an applicant has the equivalent of an American bachelor's or master's degree, the Graduate School will require such verification by an independent service such as the Center for Educational Documentation, Boston, MA (617-522-4738).

2. The degree must have been earned with a satisfactory scholastic average to demonstrate that the applicant has had adequate preparation for the field in which graduate studies are to be undertaken.

3. The applicant must have obtained a satisfactory score on the appropriate entrance examination required for admission by the program or department to which admission is sought. The official score report must be submitted; a photocopy of the examinee's report is unacceptable. Unless otherwise stated under a specific program description, the required examination is the Graduate Record Examination Aptitude Test.

4. The Commonwealth of Massachusetts requires that all full-time graduate (9 or more credits) must be immunized against measles, mumps, rubella, tetanus, and diphtheria. In addition, all students in the College of Health Professions and international students, regardless of age or enrollment status, must show proof of immunization. Students will not be permitted to register for courses at the University unless proof of immunization has been sent directly to the Director of Student Health Services, University of Massachusetts Lowell, Lowell, MA 01854 (978-934-4991).

Departmental Requirements

The rules, regulations, and policies delineated by the Graduate School constitute only the minimum requirements for admission, retention, and graduation. Each department may have additional requirements mandated by the unique nature of its programs. It is the responsibility of the graduate student to be aware of the minimum requirements of the Graduate School and, in addition, to fulfill the special requirements of the particular program in which he or she is enrolled.

APPLICATION PROCEDURE

On-line Application

You are encouraged to apply on-line at www.uml.edu/grad.

Conventional Application

Application forms and materials may be obtained from the University of Massachusetts Lowell Graduate School Office, Falmouth Hall 311, Lowell, MA 01854 by calling 1-800-656-GRAD, or at www.uml.edu/grad. A non-waivable and non-refundable application fee must be received before the application is processed. Each applicant must file the following documents: (1) a completed application form; (2) official transcripts of all undergraduate and graduate records; (3) three letters of recommendation written by individuals qualified to judge the ability of the applicant to carry on graduate work and research; (4) official scholastic test scores specified for various degree programs at the University (see individual departmental requirements). An applicant who has earned a graduate degree from an accredited university may petition the department graduate coordinator to waive the scholastic test requirements (e.g. GRE); and (5) the official score report for the "Test of English as a Foreign Language" (TOEFL) for students from countries where English is not the national language. If the TOEFL bulletin cannot be obtained locally, students should write well in advance to: Test of English as a Foreign Language, Box 6151, Princeton, NJ 08541-6151, U.S.A.

All test scores must be official and sent directly by the testing agency.

Application Deadline

The University of Massachusetts Lowell Graduate School has a "rolling admissions" policy. However, some programs have early, fixed application deadlines. Consequently, the applicant is strongly urged to contact the department of interest to determine the last date on which applications may be received. In general, early applications will ensure that all materials are processed on time and that a student who wishes to apply for a teaching assistantship will be given due consideration. Many programs will fill available openings several months before the beginning of the semester. A student who has been accepted into the Graduate School must attend within a year of acceptance or may, at the discretion of the department, be required to submit a new application. Application files, for individuals who do not matriculate, will be retained in the Graduate School for only two years from the date of application.

Types of Admission

A student may be admitted to graduate study at the University of Massachusetts Lowell under one of the three classifications listed below.

1. Matriculated status: A student who has met all requirements for admission to a degree program and who has been recommended by the department in which she or he proposes to study as a degree candidate.

2. Matriculated with conditions: A student who has not fully met the requirements stipulated by the program may be admitted as a prospective candidate for a degree with specified conditions to be met. Such a student must have as an initial objective the satisfactory completion of all requirements for full matriculation.

3. Non-Degree status: An individual without advanced degree objectives may take courses in certain programs with non-degree status. A student who wishes to take courses as a non-degree student must submit a transcript indicating the conferral of a bachelor's degree. If the student does not provide a transcript, he or she will be prohibited from taking additional graduate courses. Such a student is not eligible to receive credit toward a degree unless he or she files a formal application and is then admitted as a matriculated student.

The maximum number of graduate credits a student may complete with non-degree status is 12. Graduate credits earned beyond the 12 credit limit when a student holds non-degree status will not be counted toward a graduate degree if a student is later accepted into a program.

International students are not eligible for non-degree status.

Graduate Readmission/Deferral Policy

1. A matriculated student who formally withdraws in good standing from the university may be re-admitted by completing an academic petition within two years of withdrawal. The petition must be signed by the graduate coordinator of the department and submitted to Graduate Admissions.

2. A matriculated, or newly accepted student who is dropped from a graduate program for failure to register must submit an academic petition to Graduate Admissions within one year of being notified that he or she has been dropped, requesting re-instatement in the program. If the one year time period is exceeded, the student must submit a new application and fee.

3. A student may request a deferment of acceptance up to one year beyond the date when he or she was scheduled to begin his or her graduate program. If the one year time period is exceeded, the student must submit a new application and fee.

Acceptance of Foreign or American Master's Degree Toward Doctoral Requirement

Students accepted into a doctoral program who hold a master's degree in the same or a closely related discipline from a U.S. or foreign academic institution will have their transcripts and supporting documentation reviewed by the department graduate committee. The committee may choose one of the following actions:

1. approve all coursework + thesis for the master's degree up to the total number of credits granted by the University of Massachusetts Lowell department for its master's degree, and thereby require the student to complete only "beyond the master's" course/dissertation credits for the doctorate;

2. accept the U.S. or foreign master's degree, but because of deficiencies in the student's master's program, require a limited number of graduate courses to be added to the total credits required for doctoral degree completion "beyond the master's";

3. require that a student with a U.S. or foreign master's degree obtain a University of Massachusetts Lowell master's degree before proceeding to the doctorate.

All coursework for U.S. or foreign master's degrees considered for approval by the department must be at a grade level of B or better. Official, documented verification of the degree awarded must also be provided.

Transfer Credit

The following are minimal guidelines for transfer of credit; individual departments are free to impose more stringent requirements. Only courses completed elsewhere in the United States within five years prior to the date of admission to a graduate degree program at the University of Massachusetts Lowell may be considered by the faculty of the department for transfer in accordance with the following regulations.

1. A maximum total of 12 graduate credits earned with a grade of B or better taken at the University of Massachusetts Lowell and/or another accredited institution may be transferred to a master's degree program (see individual programs for further restrictions, if any). A maximum of 24 credits with a grade of B or better may be transferred to a doctoral program.

2. Grades of C or better for courses taken at UMass Lowell when the student held non-degree status may also be transferred (by Academic Petition) into a degree program. However, the 6 and 9 BC/C credit graduation limit for master's and doctoral degrees, respectively, (see Retention Policy) and calculation of the cumulative grade point average based on all graduate courses taken at the University (see Academic Grades) remain in effect.

3. An official transcript and description of the course(s) must be submitted with the written request.

4. The courses presented must be from an accredited U.S. or Canadian institution authorized to grant graduate degrees.

5. The courses presented for a master's degree must not have been used in earning another master's degree and must be beyond the baccalaureate credit requirement.

6. The courses presented must be appropriate to the degree program for which the applicant is applying.

7. The courses presented must be graduate level.

8. Transfer credit may not be granted for research seminars, clinical courses, practica, internships, or special projects.

9. Transfer credit from another U.S. or Canadian institution must not exceed equivalent course credit (typically 3) at UMass Lowell, and will be based on Lowell's standard of 37.5 semester contact hours = 3 credits. One and two course credit transfers will also be considered providing they are proportional to the 37.5 semester contact hour standard.

10. Students who wish to transfer credit must file (within the first semester of matriculation) the Academic Petition form available from the Graduate School Office.

11. With the approval of the department, a maximum of 6 credits of UMass Lowell 400 level courses, not used for the baccalaureate degree, may be considered for transfer and counted toward the graduate degree.

Graduate Equivalency Credit

For Business Administration and Work Environment programs, graduate equivalency credits may be given, at the discretion of the department, for accomplishments, such as professional certification, related work experience, etc., which substantially demonstrate that the student has equivalent knowledge and hence should not be required to take a particular course or courses. Requests for graduate equivalency credit must be presented to the department graduate coordinator on the standard Graduate Academic Petition, must specify the course number and credits for which the substitution is being given, and must be accompanied by official documentation which justifies the equivalency credit. If approved by the department and college dean, the stu-

dent's transcript will list the graduate equivalency credit granted.

A maximum of twelve graduate equivalency credits may be applied to the Master of Business Administration or the Master of Science degree in Work Environment.

REQUIREMENTS FOR DEGREE CONFERRAL: COMBINED BACHELOR'S/MASTER'S DEGREE PROGRAMS

In order to encourage outstanding undergraduate students to continue their studies toward an advanced degree, a number of departments have instituted a program of accelerated study which leads to combined bachelor's and master's degrees. Currently, such a program is offered in the following departments/programs: Biological Sciences, Chemical and Energy Engineering, Civil Engineering, Computer Science, Criminal Justice, Electrical and Computer Engineering, Clinical Laboratory Sciences, Mathematics, Mechanical Engineering, Plastics Engineering, Psychology, and Radiological Sciences.

Every full-time student with a grade point average of 3.0 or above at the end of his or her junior year who is enrolled in a department offering the accelerated baccalaureate and master's degree program is eligible to be admitted to that program.

Admission to the combined baccalaureate and master's degrees is an honor conferred on the student that carries with it distinct benefits. Graduate Record Examination scores are not required, except in the Graduate School of Education, and some departments offer course credit benefits. The student may or may not decide to take advantage of the honor conferred, and can graduate with a bachelor's degree in exactly the same way as a student not admitted to the accelerated program.

Graduate courses taken by a baccalaureate degree student that are credited toward the master's degree must have been obtained with a grade of B or better. The credits that count toward the baccalaureate and master's degrees are determined by individual departments by choosing from one of the following three options:

Option A: Up to 12 graduate credits (500 level or higher), as part of the departmental baccalaureate major requirement, may be used for both the undergraduate and graduate degrees provided these graduate credits were taken in excess of the university minimum of 120 baccalaureate degree credits.

Option B: Once the departmental credit requirements for the major have been met, up to twelve graduate credits (500 level or higher) in excess of the 120 credit baccalaureate degree may be used for the graduate degree.

Option C: Up to six credits of graduate (500 level or higher) courses may be used by a student in the baccalaureate/master's degree program for both graduate and undergraduate degrees.

The Graduate School of Education, and the departments of Regional Economic and Social Development and Work Environment, which are graduate only, offer undergraduates from a number of majors the opportunity to participate in combined baccalaureate/master's programs. Interested juniors should contact their participating undergraduate departments. Each participating department, in agreement with the graduate-only college/department, has selected one of the options A, B, or C listed above.

MASTER'S DEGREE REQUIREMENTS

Advising

An entering graduate student should meet with the departmental graduate coordinator as soon as possible after arrival on campus. The coordinator will:

1. help design and then approve the student's complete program leading to the master's degree;
2. recommend course credits from within and outside the University for transfer into the student's degree program;
3. monitor the student's progress toward the degree, which must be completed within a five-year time period in most programs (See Time for Completion of Degree Requirements).

General Requirements for the Master's Degree

To be recommended for a master's degree, a candidate must satisfy all requirements of the Graduate School and the specific requirements of the department in which he or she is enrolled. The requirements of the Graduate School are listed below, and the specific requirements established by the various departments may be found in the section describing the particular programs.

A candidate for the master's degree must complete the following within five years of matriculation in order to receive the degree:

1. A course of study designed by the department in which he or she is enrolled must be completed and approved by the Graduate School. The course of study must have a minimum of 30 credit hours of graduate work including, where applicable, a thesis or project in the student's chosen field.
2. A student must successfully pass an oral or written examination on his or her complete master's program if required by the department.
3. Satisfactory grades in all subjects offered for the degree must be earned (See Retention Policy).
4. All financial obligations, including tuition, fees, and expenses, must be satisfied as evidenced by completion and submission of a signed Graduate Degree Clearance form to the Graduate School Office.

Research Option for the Master's Degree

If required by the program, a student must complete a master's project or a thesis. The proposal must be approved by the department in which the student is enrolled and the final project or thesis must be of graduate level quality.

Project

The project must consist of a scholarly investigation, such as a review, report, synthesis, design or experiments in the student's field resulting in a comprehensive written document. Usually, if a student chooses the project option, he or she is required to take additional course credits. Each project is awarded only three to four credits and is intended to be completed within the time limit of one semester. If the work for a project is not completed by the end of the semester, the instructor will give the student an "I"/grade which is to be treated the same as an incomplete for a regular course.

Thesis

The requirements for a thesis are much more extensive, including the completion of acceptable research and its defense before a thesis committee. The completed thesis must conform to the format specified in the "Thesis Guide" which is available in the Graduate School

Office. The format of all theses must be approved by the Graduate School. The time required for completion may vary; if a student has not completed the thesis by the end of the semester, but is making satisfactory progress, he or she is given the grade of "PR". If the student requires the use of university resources to continue thesis research, but has completed the required number of credits for the master's thesis, he or she may sign up for 3, 6, or 9 credits of Continuing Graduate Research (see General Regulations). However, if the student is not using University resources, but is in the process of writing the thesis, he or she may register for Continued Matriculation for the semester(s) during which the work is completed.

Upon completion of the thesis, the grade of "S" or "U" will be awarded for the last semester in which the student is registered for thesis research.

Thesis Committee

As soon as a student has chosen an area of research, a Thesis Committee is selected by the student and his or her research advisor in accordance with the policy of the department. The Thesis Committee shall consist of at least three members, at least two of whom shall be from the student's major department. One member of the committee shall be the student's thesis advisor. An outside expert, such as the supervisor of a research project conducted at an industrial setting or a faculty member from another institution, may be a member of the committee, but that individual must possess academic credentials which would qualify him or her to serve as a member of the University of Massachusetts Lowell faculty. The responsibilities of the Thesis Committee shall be to:

1. approve the research topic;
2. supervise the progress of the thesis;
3. read, evaluate and approve or disapprove of the written thesis;
4. hear, evaluate and approve or disapprove of the oral defense of the thesis;
5. report the completion of all thesis requirements to the department and the Graduate School.

Thesis Preparation

Every graduate student who completes a thesis is required to bear the cost of microfilming and of binding two copies of the manuscript for the University's files. Copywriting is optional and available for an additional fee.

Thesis Defense

One week prior to the thesis defense, announcements of the defense listing the candidate's name, thesis title, and place and time of the defense, must be submitted to the chairperson of the department, the college dean, and the Graduate School Dean for posting and distribution. The defense is open to the public.

Procedure for students accepted into a master's degree program who decide to continue on for the doctorate but want to first complete their master's degree.

1. The student must complete all required courses, compile a 3.0 grade point average, and successfully defend his/her thesis, if required.
2. The student must complete the Graduate School clearance process for the master's degree.
3. A student is prohibited from enrolling in doctoral research until he or she has completed the clearance process for the master's degree.
4. The student must then apply to the doctoral program by completing the standard application process.
5. Official admission into a doctoral program and receipt of a letter of acceptance are contingent upon completion of the clearance process for the master's degree.

DOCTORAL REQUIREMENTS

The University of Massachusetts Lowell offers the Ph.D. in Chemistry, Nursing, Polymer Science, Physics, the Sc.D. in Computer Science and Work Environment, the D. Eng. in Electrical, Mechanical, and Plastics Engineering, and the Ed.D. in Education. Requirements for each program vary considerably, but those which apply to all programs are listed below. Applicants should refer to the specific program for additional requirements. It is possible to obtain a master's degree if a student has completed the requirements and decides not to pursue the doctorate. Full-time faculty of the University of Massachusetts Lowell are not eligible to earn a doctorate from Lowell during their employment.

Advising

Until such time as the doctoral student chooses a research advisor, the Graduate Coordinator in the department will advise the student in terms of course selection, degree requirements, departmental/ university graduate policies, etc. Once the advisor has been selected, he or she will:

1. monitor and approve the student's program of study leading to the doctorate;
2. recommend to the coordinator of the program course credits from within and outside the University for transfer into the student's doctoral program;
3. approve the procedure by which the student intends to satisfy the language requirement (if any);
4. advise the student in regard to the qualifying examinations;
5. meet regularly with the student to determine his or her progress toward the degree and help solve any problems that may arise; and
6. report on the student's progress to the Graduate Coordinator of the program.

Residence Requirement

The equivalent of at least one academic year of full-time graduate work must be spent at the University. The requirement for a year in residence may be satisfied only by the student's physical presence on campus for two consecutive semesters. This may be satisfied by a fall-spring sequence, a spring-fall sequence, or a 12 week summer session immediately preceded or followed by a semester of the regular school year.

Language Requirement

Individual departments will determine the number, if any, of foreign or computer languages and the level of competency required of doctoral students.

Doctoral Research

In addition to the other requirements of the Graduate School, a candidate for a doctoral degree must complete an acceptable dissertation. The dissertation must satisfy the following criteria: 1) it should demonstrate the candidate's intellectual competence and maturity in the field of concentration; 2) it should make an original and valid contribution to knowledge; and 3) it should be an individual achievement and the product of independent research. Although doctoral dissertations may result from a project involving collaboration of several scholars, the individual contribution of each doctoral candidate must be substantial, clearly identifiable, and presented separately. The Committee will judge the completed dissertation in terms of the candidate's ability to review and make critical use of the

literature; to formulate a problem, develop appropriate methodology, and work systematically toward a solution; and to summarize the material or data and draw conclusions from them. The writing should be of publishable quality.

Dissertation Committee

After a student has chosen an area of research and a research supervisor, a Dissertation Committee is selected by the student and his or her research advisor in accordance with the policy of the department. The Dissertation Committee shall consist of at least three members, one of whom is the research supervisor and at least two of whom shall be from the student's major department. An outside expert from industry or another university may be a member of the committee, but that individual must possess academic credentials which would qualify him or her to serve as a member of the University of Massachusetts Lowell faculty. The responsibilities of the Dissertation Committee shall be to:

1. approve the research topic;
2. supervise the progress of the dissertation;
3. read, evaluate, and approve or disapprove of the written dissertation;
4. hear, evaluate and approve or disapprove of the oral defense of the dissertation;
5. report the completion of all dissertation requirements to the department and the Graduate School.

Dissertation Credits

If the graduate student requires the use of University resources to continue his or her dissertation but has completed the required number of credits for doctoral research, he or she may sign up for 3, 6, or 9 credits of Continuing Graduate Research (see General Regulations). (Note: International students on F-1 or J-1 visas must be registered for a minimum of nine credits each semester). Graduate students who have completed all the requirements except the writing and defense of the dissertation and who do not need to use university resources must register for Continued Matriculation (00.601.201) and pay a fee each semester until they graduate.

Dissertation Preparation

Every graduate student who completes a dissertation is required to bear the cost of microfilming and of binding two copies of the manuscript for the University's files. Copywriting is optional and available for an additional fee.

Dissertation Defense

One week prior to the dissertation defense, announcements of the defense, listing the graduate student's name, dissertation title, and place and time of the defense, must be submitted to the chairperson of the department, the college dean, and the Graduate School Dean for posting and distribution. The defense is open to the public.

Doctoral Degree Requirements

The doctoral degree is conferred upon graduate students who have met the requirements listed below.

1. The student must successfully complete the graduate courses in the major field and the number of course and dissertation credits required by the particular program.
2. If indicated, the language requirement specified by the major department must be satisfactorily completed.
3. A qualifying examination, oral and/or written, conducted by the major department, must be passed before any work is begun on the dissertation. If the student fails the qualifying examination he or she may, at the discretion of the department, be permitted a second and final opportunity. At this point, having completed steps 1 through 3, the student is admitted to candidacy for the doctorate.
4. The residence requirement must be satisfied.
5. A dissertation based upon the results of original research, and which is satisfactory to the Dissertation Committee of the major department, must be completed.
6. A final oral dissertation defense conducted by the Dissertation Committee, based primarily upon, but not necessarily limited to, the contents of the candidate's dissertation must be passed. The examination cannot be scheduled until all members of the Dissertation Committee have had seven working days in which to read the dissertation. The oral examination is to be conducted by the Dissertation Committee, whose membership may be augmented by the non-voting faculty and representatives of the Graduate School. In order to pass the defense, the candidate may not receive more than one dissenting vote from the members of the Dissertation Committee.
7. All financial obligations (tuition, fees, and expenses) must be satisfied as evidenced by the completion and submission of a Graduate Degree Clearance form to the Graduate School Office.

Procedure for students accepted into a doctoral program who elect to instead obtain the master's degree and leave the university.

1. The student must file an Academic Petition requesting to be changed from the doctorate to the master's degree program.
2. The student's research advisor must submit to the Registrar, grade change forms withdrawing the student from doctoral dissertation and adding master's thesis for the appropriate number of credits.
3. The student must complete all required courses for the master's degree, compile a minimum 3.0 grade point average, successfully defend his/her thesis, and complete the clearance process at the Graduate School.
4. All graduate courses (and undergraduate course work used for graduate credit), whether taken for the original doctoral program or for the master's degree, will be included in the grade point average and listed under the master's degree program.

GENERAL REGULATIONS

Continuous Registration of Graduate Students

In order to maintain continuity of enrollment, it is mandatory that a matriculated student register each fall and spring until the program of study is complete and the degree has been earned. A graduate student who plans to receive a summer degree (awarded in October) must register at UMass Lowell during the previous summer session in order to maintain continuous matriculation.

If for any reason a student is not registered for a course (because of a leave of absence or because all course work except the thesis or dissertation is complete), the student must register for 00.601.201 (Continued Matriculation) in order to maintain continuous registration. Since students are not allowed to register if they have outstanding financial obligations to the university, it will be necessary for them to clear their financial record in order to register for Continued Matriculation. A master's degree candidate may register for 00.601 for not more than one academic year, a doctoral candi-

date for not more than three academic years. Continued Matriculation does not entitle a student to any use of university facilities or resources, but only maintains an active record and provides for appropriate mailings. A student working on thesis or dissertation research who needs to use the university libraries, laboratories, or other resources must pay an additional fee.

All international students on F-1 or J-1 visas must register as full-time students (9 credits) each semester until their degree requirements are completed. Any variance from this policy must be approved by the Dean of the Graduate School.

A student who fails to maintain continuous matriculation loses the status of a degree candidate and must reapply to the Graduate School for readmission and for renewal of candidacy.

Maximum Semester Credit Limit

The usual course load for full-time graduate students is 9 credits/semester. Depending upon the program requirements and abilities of the student, individuals may carry more than 9 credits each semester. However, the absolute maximum number of total credits (undergraduate + graduate) for which a graduate student will be allowed to register is 18 credits/semester.

Continuing Graduate Research

Once a student has completed the required number of credits for master's or doctoral thesis/dissertation research with grades of PR or S (see summary of degree credit requirements), he or she will not be allowed to sign up for additional thesis/dissertation research credits. Instead, if required for teaching/research assistantships or immigration/visa purposes, the student may enroll in 3, 6, or 9 credits of Continuing Graduate Research designated _ _763, 766, or 769_ _ _ where the first two blanks represent the departmental designation, 3, 6, and 9 indicate the respective number of credits, and the last three blanks are the standard numbers which code to a particular faculty member in the department.

Statute of Limitations (Time Limit for Degree Completion)

A graduate degree, at either the master's or doctoral level, implies a significant mastery of a discipline within a specified time period. A well designed curriculum is not a mere collection of classes that add up to a set number of credits. It is, rather, a coherent selection of courses with an overall educational achievement that is greater than the sum of its parts. However, this coherence is lost if the program is completed over a long time span. Consequently, degree requirements for the master's degree must be completed within a **five-year** period from the semester of admission. For those master's programs requiring 45 credits, the time limit is six years. The doctoral degree must be completed within an **eight-year** period beginning with the semester of admission as fully matriculated or matriculated with conditions. A student may obtain an extension of one year by filing an Academic Petition signed by his or her coordinator, department chair, college dean, and the Dean of the Graduate School. In exceptional cases, an additional extension may be granted by the Graduate Policy and Affairs Committee. In this case, the student must submit an Academic Petition, a letter of explanation accompanied by a detailed plan for degree completion, and a letter from the student's coordinator or thesis advisor concurring with the request.

Course Numbering System and Designation

400-499 Undergraduate courses usually designed for juniors or seniors; no more than six credits may be taken for graduate credit with the permission of the graduate coordinator.

500-599 Courses for graduate credit, but which may be taken by advanced undergraduates with the advisor's permission.

600-699 Graduate courses which are open only to graduate students.

700-799 Seminars, special topic courses, projects, or thesis research for advanced candidates in master's and doctoral degree programs.

Each course offering is designated by a two-digit prefix and a three-digit course number (e.g., 81.529). The two digit college prefix identifies a college department and/or special area. The three-digit course number identifies the course level.

Course Prefixes

Each college department and/or special subject area has been assigned an identifying two digit number within the numerical ranges specified as follows:

Education	01-09
Engineering	10-28
Health Professions	29-39
Liberal Arts	40-59
Management	60-69
Fine Arts	70-79
Science and Math	80-99

Credit Designation

Arabic numbers enclosed in parentheses indicate the number of hours of lecture and/or laboratory. The arabic number following the numbers in parentheses is the designation of course credit. For example (3-3)4 indicates a course with a lecture for three hours, a laboratory for three hours, and for which four credits is awarded.

Academic Grades

The grading system uses grades A, AB, B, BC, C and F with the numerical equivalents of 4.0, 3.5, 3.0, 2.5, 2.0 and 0. The following special grades are also used: I (Incomplete/Grade), S (Satisfactory, B or better), U (Unsatisfactory, for projects, theses/dissertations, and seminars only; no credit granted), AU (Audit), W (Withdrawal from a course or from the University), X (Withdrawal because of illness or personal emergency),Y (Administrative dismissal), Q (Never attended but did not withdraw), PR (In Progress for theses or dissertations), and NC (No Credit for theses or dissertations where no progress has been made). A student registering for research will do so in 3-credit multiples each semester up to the total number recommended. **No graduate degree will be awarded to a student whose cumulative average for course work in his or her program is below 3.0.** Some programs may require a higher grade point average for graduation. The cumulative grade point average is computed from all graduate level courses taken for a grade at the University of Massachusetts Lowell and from any undergraduate courses taken at the University which have been approved by Academic Petition to be transferred into the graduate program.

Grade Exclusion

A request may be submitted to omit a specific course (grade and credits) from the GPA for matriculated students. Such a request must be presented on an Academic Petition, provide detailed justification for the specific action, and certify that the action has been approved by a majority of the departmental graduate committee. Only one grade exclusion in

total, including a grade for a repeated course, will be permitted for each degree sought by the student as recommended by the departmental graduate committee. However, the official transcript will list grades for all undergraduate and graduate courses taken at the University. The designation XG, excluded from the grade point average, will appear alongside a course grade on the transcript if so approved by the departmental graduate committee. Grade substitutions are not permitted.

Grades for Projects, Theses/Dissertations and Seminars

Projects (Enrollment Restricted to Matriculated Graduate Students):

Only one of three grade designations will be allowed for projects:

S for projects completed at a satisfactory level

U for unsatisfactory completion of a project (no credit toward degree requirements)

I/U

Theses/Dissertations (Enrollment Restricted to Matriculated Graduate Students):

PR will be given for thesis/dissertation research if the student has made satisfactory progress during the semester.

NC will be given if the student has made no progress during the semester on thesis/dissertation research.

Once the thesis/dissertation research has been completed and evaluated by the research advisor and thesis/dissertation committee, the advisor will issue one of the following grades:

S Satisfactory
U Unsatisfactory
(no credit toward degree requirements)
I/U

Seminars:

S Satisfactory
U Unsatisfactory
(no credit toward degree requirements)
I/U

When the research advisor and committee members agree that a student's thesis/dissertation has been successfully completed, the advisor will issue the grade of "S" for the final semester of thesis/dissertation research. All previous PR's for thesis/dissertation will then count as satisfactory for degree completion although they will remain as PR on the official transcript.

Under no circumstances will letter grades (A, AB, etc.) be allowed for pro-

Incompletes

If, because of unusual circumstances, a student is unable to meet all the requirements of the course by the end of a semester, the designation Incomplete/ Grade may be given. The award of this grade requires an **agreement** between the instructor and the student concerning the completion of course work (see below). Under no circumstances will a student be allowed to graduate with incomplete(s) on his or her transcript.

Faculty members who issue incompletes to students will be required to use the I/Grade system. Prior to completion of the missing work, the I/grade will not be computed into the grade point average (GPA). However, if the student does not complete the missing work in the time period specified for graduate students (see accompanying agreement), the student's grade will automatically change to that listed on the right side of the slash mark and be computed into the GPA. The grade listed on the right of the slash mark must be one that has been approved for graduate student grading. If the student completes the missing work in the specified period, the instructor must evaluate the work and turn in a grade change form to the registrar's office as summarized in the following agreement.

UNIVERSITY OF MASSACHUSETTS/LOWELL
Office of the Registrar
Academic Agreement
Incomplete Grades for Graduate Students

Student Name: _____ Student I.D.# _____

Course/Section: _____ Instructor's Name: _____

Course Title: _____

To Student and Instructor: Please read this document carefully.
It is an academic agreement which should be entered into only after careful consideration of the circumstances which prevented the student from completing the course requirements. This agreement is designed to protect both the student and faculty. Your signatures at the end of the document indicate that you agree to abide by all conditions indicated below.

Instructions to Student: You hereby signify that the following specific work is needed to complete your course. Your signature below indicates that you agree to complete this work and turn it in to your instructor according to the specified time schedule.

Specific work needed to complete course: _____

_____

Instructions to Instructor: Your signature at the end of this form indicates that you have agreed to assign the designation incomplete/grade to the above student. Furthermore, you agree that the above statement is an accurate description of the missing work for this course, and that you will evaluate this work when it is given to you and assign a final grade for this course according to the time schedule listed below. A grade change (from I to grade) signed by you and the college dean must be submitted to the Registrar before the last day of next semester (see below).

Time Schedule: The maximum time limit for the submission of all missing course work necessary for removal of an incomplete is two weeks before the last day of classes (not the final exam period) of the next semester following the semester (or summer session) in which the grade was received. What this means is that the student must turn in the missing work two weeks before the last day of classes. The instructor must evaluate the work during this two week period and turn in a grade change form (signed by the college dean) to the Registrar before the last day of classes. After that time, if the work has not been completed, the student's grade will automatically change to the grade listed to the right of the slash mark and be computed in the student's GPA.

Extensions: In extraordinary circumstances, a one semester extension of the time limit for completion of the work is possible.

Requests for a one semester extension must be presented to the Graduate Dean on an Academic Petition prior to the expiration date stated above. The petition must be signed by the Instructor and College Dean. An academic plan, signed by the student and instructor, must accompany the Academic Petition and provide an explanation of why the extension is required and a detailed statement of how the student will complete the missing work. If approved, the petition and academic plan will be retained in the student's file in the Graduate School. In the interim, the course grade to the right of the slash mark will be listed on the transcript, computed in the GPA, and remain as such unless the work is completed and the instructor turns in a grade change form according to the above time schedule.

Signature of student _____ Date _____

Signature of instructor _____ Date _____

Course Listing on the Graduate Transcript

All graduate courses for which a student registers (including repeated courses) are listed on the transcript and are used to calculate the student's grade point average whether or not they are taken to fulfill degree requirements. In addition, undergraduate courses which a student takes to fulfill prerequisite requirements before or during matriculation in a graduate program, or for personal enrichment, will also be listed on the transcript. A departmental graduate committee may recommend to the Dean of the Graduate School that this requirement be modified.

Audit

A graduate student may, upon approval of the advisor and the instructor, register for a course on an audit basis, but must pay the full amount of tuition and fees. An audit student is not required to take tests or the final examination. A change in registration from audit to credit or credit to audit must be done during the add/drop period. Under no circumstances can a course taken for audit be given credit at a later date.

Dropping Classes and Refund Policy

Graduate students may drop courses during the first **ten** days of classes and receive a full refund. No refund will be given after the **tenth** day of the semester. To formally withdraw from a course during this period, or thereafter, the student must submit a drop form to the Graduate School, not the Registrar's Office. If the student fails to officially drop a course, he or she will remain enrolled and be required to pay for tuition and fees. In addition, if the student does not drop a course and does not attend classes, he or she will receive an "F" on the official transcript.

Withdrawal

A student finding it necessary to withdraw from a course must do so within the time specified in the graduate academic calendar. The student's permanent record will indicate a grade of W for the course(s) from which he or she has withdrawn unless the withdrawal has taken place within the first 10 class days of the semester, during which time no record will be kept.

A student who wishes to withdraw from the University must obtain the appropriate signatures on the withdrawal clearance form and submit it to the Graduate School. This procedure ensures that the student's academic and financial obligations are cleared before leaving the University. If a student officially withdraws from the University, the permanent record will indicate a grade of W. If the student fails to follow the official withdrawal procedure and does not withdraw in good standing, official transcripts of the student's academic record will not be issued and the student will not be permitted readmission to the Graduate School except under extenuating circumstances. A student's file will remain active up to two years after withdrawal. At any time during this period, a student who has officially withdrawn may request readmission by completing an Academic Petition which must be signed by the graduate coordinator, chairperson, and college dean. After two years, a student must file a new application in order to be readmitted to the Graduate School.

Graduate Credit for Undergraduate Courses

UMass Lowell courses at the 400 level are designed for seniors, but under certain circumstances may be taken by graduate students for graduate credit. A maximum of 6 credits of 400 level courses may be used for credit toward the graduate degree. Three hundred level courses and below are never counted toward a graduate degree. If a graduate student takes certain undergraduate courses to make up background deficiencies or for satisfying language requirements, the course credit hours are not used as part of the graduate degree program, but will appear on the graduate transcript.

Undergraduate Credit for Graduate Courses

A qualified junior or senior may take a course at the 500 level for undergraduate credit in accordance with the policy and procedures of the department or college in which the course is offered. The grade received in any such course is used in calculating the undergraduate's cumulative grade point average. Such a student may not earn graduate credit for the course until he or she has completed all requirements for the bachelor's degree. Counting of graduate credits for both the bachelor's and master's degrees is subject to departmental requirements.

Changes in Registration

Courses may be added or dropped by completing the appropriate add/drop forms and obtaining the permission of the course instructor and the student's advisor during the first 10 academic days of the semester. In addition, students may change from audit to credit or from credit to audit during this period. Courses dropped during the first 10 academic days will not appear on the student's permanent record. No new courses may be added and no course may be changed from audit to credit after the 10th academic day. Thereafter, a student wishing to drop courses must do so by the date indicated in the Graduate School Academic Calendar. The grade for these courses will appear as W on the student's record. All changes in registration must be brought by the student to the Graduate School Office for processing or they will not appear on the student's record.

Change of Program

A graduate student wishing to change departments or transfer to a doctoral program upon completion of his or her master's degree must follow the steps listed below:

1) No transfers will be considered until the student has enrolled in courses of the original department in which he or she was accepted for at least one semester.

2) All sections of a new application sheet must be completed;

3) If so desired, the student may request that the GRE scores, letters of recommendation, etc., in his or her original file be used as part of his or her new application package.

4) The student must specify on the application form when his or her master's degree will be completed and when he or she will actually begin doctoral studies (for students applying to a doctoral program).

5) A check made payable to University of Massachusetts Lowell to cover the application fee must be included.

6) A University of Massachusetts Lowell transcript of all courses taken at the University must be attached to the application.

Transcripts

In order to obtain a transcript, a student must submit his or her name, major and year attended or graduated to the

Registrar's Office through a written request by mail or by filling out the appropriate forms available in the Registrar's Office. Transcripts given directly to students do not carry the University seal and are not official. The seal is attached when the transcript is mailed directly from the University to the receiving party.

Retention Policy

No more than 6 credits of C and/or BC may be counted toward the master's degree; no more than 9 credits of the same grades may be counted toward the doctorate. **No graduate degree will be awarded to any student whose overall cumulative grade point average falls below 3.0.**

Any graduate student whose **semester** grade point average (GPA) falls below 3.0 will automatically receive a **warning notice** which will also be sent to the graduate coordinator, and filed with the student's record in the Graduate School. The student will be required to meet with the graduate coordinator or his/her designee within 30 days of receipt of the warning notice and develop an academic plan to bring his or her GPA to a level above 3.0.

Any graduate student whose **semester** GPA falls below 3.0 for a **second time**, will automatically receive **a letter of probation**. Copies of the letter will be sent to the graduate coordinator, chairperson, college dean, and also placed on file with the student's record in the Graduate School. Within 30 days, the department graduate committee, chaired by the graduate coordinator or his/her designee, will meet with the student and decide whether to recommend **loss of degree candidacy**. Such a decision or other course of action will be fully documented in writing with copies sent to the chairperson, college dean, and the dean of the Graduate School. A recommendation of loss of degree candidacy and dismissal are subject to the approval of the college dean.

Any student whose semester GPA falls below 3.0 for a **third time**, and whose **cumulative** GPA is below 3.0, will automatically be **dismissed** from his or her graduate program and the University. Reinstatement will be considered if the student provides a detailed justification and academic plan concerning how he or she will correct this academic deficiency. The plan must be attached to a Graduate Academic Petition and approved by the graduate coordinator, chairperson, the college and the graduate deans, and the Provost/Vice Chancellor for Academic Affairs or his /her designee. **If any of the above individuals disapproves of the reinstatement, the dismissal will remain in effect and no subsequent appeals will be considered.**

Independent of the above warning/probation/dismissal system, the Dean of the Graduate School may at any time examine the performance of any student not living up to the academic standard expected of graduate students and recommend to the appropriate graduate committee a course of action including dismissal.

UNIVERSITY APPEALS PROCESS REGARDING ACADEMIC (NON-MISCONDUCT) ISSUES OF GRADUATE STUDENTS

The underlying purpose of the University's appeals procedure is to guarantee due process and to protect the rights of both students and faculty in graduate programs. The following procedure provides a mechanism for formal adjudication of any academic issues (non-misconduct) which may arise. Responsibility for initiation of each of the steps belongs to the student.

Step 1. If the conflict cannot be resolved through an informal discussion between the student and the instructor, coordinator and/or individual with whom the student has a conflict (which discussion is not mandatory), the student may initiate a formal appeal.

The formal appeal, in writing and containing the pertinent facts, should be presented by the student to the Chairperson of the Department within two months of the occurrence that precipitated the appeal. Any appeal made outside this time period shall not be considered by any university body. The chairperson of the department shall appoint a committee composed of faculty members in the department. Within two weeks, or as soon as possible thereafter, this Committee shall convene and discuss the appeal with the student and the instructor, coordinator, or individual with whom the student has a conflict. The student may be accompanied by his/her faculty advisor or faculty representative. The Departmental Committee, by a majority vote after deliberations with only members of the committee present, shall render a decision within five working days and notify the appropriate parties in writing of the rationale for the decision and provide a summary of the facts which the committee considered in reaching its decision.

Step 2. If the decision of the Departmental Committee is not satisfactory to the student, the student may forward the appeal to the College Dean within two weeks of the decision of the Departmental Committee. Within two weeks, or as soon as possible thereafter of the filing of this appeal, a committee appointed and chaired by the dean or his/her designee shall convene and hear from the student and his/her faculty advisor or a faculty representative. The College Committee shall consist of a representative group from the Graduate Coordinators of graduate programs within the college possibly augmented with faculty appointed by the College Dean. The following can be present at their option: the Departmental Committee which made the decision that is being appealed, the instructor, coordinator and/or individual with whom the student had the conflict. The College Committee shall render a decision by majority vote after deliberations with only members of the College Committee present and notify the student and the department within five working days of the decision with its rationale and a summary of the facts which the Committee considered in reaching its decision.

Step 3. If the decision of the College Committee is not satisfactory to the student, the student may forward a written appeal to the Graduate Policy and Affairs Committee (GPAC) within ten working days after the decision of the College Committee. GPAC will schedule a hearing within twenty working days or as soon as possible thereafter, following receipt by its chairperson of a written request from the student. At the hearing the student may be represented by his/her faculty advisor, a faculty representative, or some other representative from the university community, and the University may be represented by the instructor, coordinator or individual with whom the student has a conflict, the Departmental Committee and/or College Committee that were convened subsequent to the appeal by the student.

A request for recording and preparing a transcript of the evidentiary portion of the hearing may be made at the time of

the appeal. The recording will be made by GPAC and the recording will remain under university control. A transcript of the recording will be made on written request of the student. After the evidentiary portion of the hearing is concluded, GPAC will deliberate with only members of GPAC present to render a decision. GPAC will notify all parties to the appeal, in writing, within five working days of the hearing, of its decision and the rationale for its decision. All information accumulated during the hearing will be forwarded to the Dean of the Graduate School to be kept on file for two years. The decision of GPAC is final.

Every reasonable effort shall be made to meet all time limits set forth in these procedures. However, with the exception of the time limit for filing of the initial appeal by the student, all time limits may be extended at the discretion of the chairperson/head of the Department (for Step1), the College Dean (for Step 2), or the GPAC Chairperson (Step 3).

The University will make all reasonable efforts maintain the confidentiality of these procedures, to the extent permissible by law. Confidentiality, however, cannot be guaranteed.

UNIVERSITY DISCIPLINARY PROCEDURES FOR GRADUATE STUDENTS: Administrative, Dismissal from the University, Academic Misconduct, Non-Academic Misconduct

Administrative Dismissal

Administrative dismissal may be invoked when a student fails to comply, after due notice, with an administrative regulation of the University. Examples of some conditions which justify administrative dismissal are listed in the Undergraduate Catalog and apply to all students, undergraduate and graduate.

Academic Misconduct

Allegations of academic misconduct are handled within the department and college by the Process of Notification and Adjudication described in the Undergraduate Catalog. The informal and formal procedures stated therein apply to both undergraduate and graduate students. Described below are some examples of violations which constitute academic misconduct.

DEFINITIONS OF ACADEMIC DISHONESTY AND PROHIBITED ACADEMIC PRACTICE AND BEHAVIOR

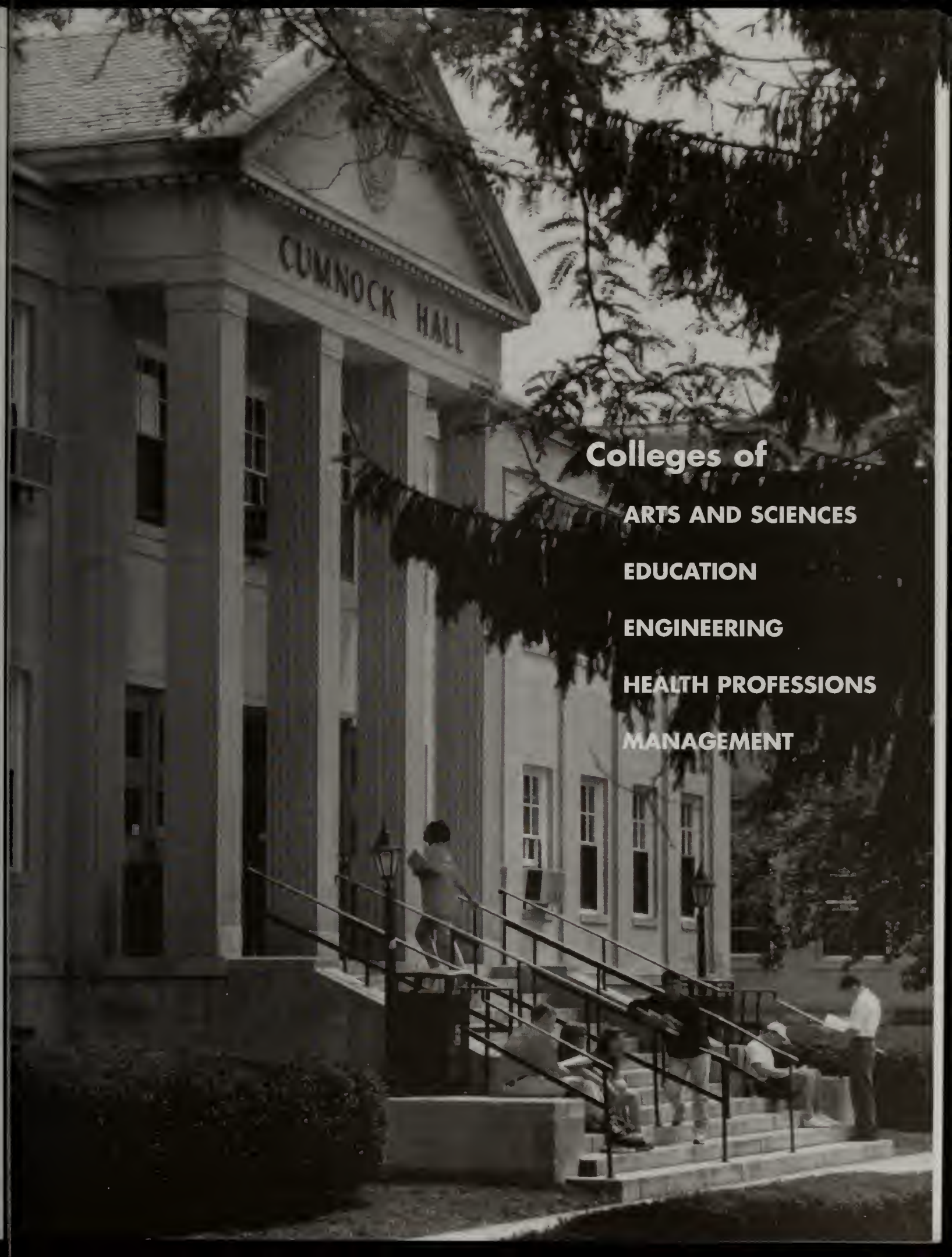
The following definitions are provided for the information of all students and constitute official notice of prohibited academic practice and behavior.

Cheating is defined as (1) misrepresenting academic work which has been done by another as one's own efforts - whether such misrepresentation has been accomplished with or without the permission of the other individual; (2) utilization of prohibited assistance (whether in the nature of a person or a resource) in the performance of assignments and examinations; (3) copying of another person's work or the giving or receiving of information or answers by any means of communication during an examination; (4) utilization of the services of a commercial term paper company; and (5) the unauthorized or fraudulent acquisition and or use of another's academic property.

Plagiarism is defined as (1) direct quotation or word-for-word copying of all or part of the work of another without identification or acknowledgment of the quoted work; (2) extensive use of acknowledged quotation from the work of others which is joined together by a few words or lines of one's own text; and (3) an unacknowledged abbreviated restatement of someone else's analysis or conclusion, however skillfully paraphrased.

Non-Academic Misconduct

Improper conduct or behavior of graduate students is subject to the University of Massachusetts Lowell Student Conduct Code and Judicial Process. Copies of this document may be obtained from the Office of Student Services, Cumnock Hall.



Colleges of

ARTS AND SCIENCES

EDUCATION

ENGINEERING

HEALTH PROFESSIONS

MANAGEMENT

College of Arts and Sciences

Dean of Fine Arts, Humanities and Social Sciences
Nancy Kleniewski
Professor of Sociology; A.B., Emmanuel College; M.A., Ph.D., Temple University.

Dean of Sciences
Robert H. Tamarin
Professor of Biological Sciences; B.S., Brooklyn College of the City University of New York; Ph.D., Indiana University.

The College of Arts & Sciences offers 27 programs of graduate study including Master of Arts, Master of Science, Doctor of Science, and Doctor of Philosophy Degrees in a variety of fields. These degree programs are part of the University's commitment to develop regional and national economies by providing state-of-the-art educational programs beyond the bachelor's degree. A wide range of on-going research and project opportunities exist within the various degree programs, and interdisciplinary study is emphasized. Graduates of these programs are heavily recruited both regionally and nationally by industry and governmental agencies.

MASTER OF ARTS DEGREES (M.A.)

- Community Social Psychology
- Criminal Justice

MASTER OF SCIENCE DEGREES (M.S.)

- Biological Science
  - Biotechnology option
- Chemistry
- Computer Science
- Environmental Studies
- Atmospheric Sciences Concentration
- Mathematics
  - Applied Mathematics Option
  - Mathematics for Teachers Option
  - Statistics Option
  - Scientific Computing Option
- Physics
  - Optical Sciences Option
- Radiological Sciences and Protection

DOCTOR OF PHILOSOPHY DEGREES (PH.D.)

- Chemistry
  - Biochemistry Option
  - Environmental Studies Option
- Physics
- Applied Mechanics Option
  - Energy Engineering Option
- Radiological Sciences
- Polymer Science
- Polymer Science/Plastics
  - Engineering Option

DOCTOR OF SCIENCE (SC.D.)

- Computer Science
  - Mathematical Science Option

DEPARTMENT OF Biological Sciences

Department Chair
Robert D. Lynch
Professor; A.B., Northeastern University; M.S., D.Sc., Harvard School of Public Health.

Graduate Coordinator
Ilze B. Skare
Associate Professor; B.A., University of Connecticut; Ph.D., Duke University.

Faculty
Susan J. Braunhut
Associate Professor; B.A., Kent State University; M.A., University of Hartford; M.A., Ph.D., Columbia University.
David T. Eberiel
Professor; B.S., Bethany College; M.S., Tufts University; Ph.D., Boston College.
Garth F. Hall
Assistant Professor; B. Sc., McGill University; Ph.D., Yale University.
Jerome L. Hojnacki
Professor and Dean of the Graduate School; B.S., Southern Connecticut State University; M.S., University of Bridgeport; Ph.D., University of New Hampshire; M.H.A., Clark University.
John C. Mallett
Professor; B.S., College of the Holy Cross; M.S., Ph.D., University of Rhode Island.
Thaddeus V. Osmolski
Professor; B.S., University of Rhode Island; Ph.D., Brown University.
Ezequiel R. Rivera
Professor; B.S., Sul Ross State College; M.S., Purdue University; Ph.D., University of Texas (Austin).
Juliette Rooney-Varga
Assistant Professor; B.A., Colby College; Ph.D., University of New Hampshire.
Thomas B. Shea
Professor; B.A., M.S., University of Massachusetts Boston; Ph.D., Northeastern University.
Robert Tamarin
Professor and Science Dean of the College of Arts and Sciences; B.A., Brooklyn College; Ph.D., Indiana University.

The following degree programs are available: Master of Science in Biological Sciences; Master of Science in Biological Sciences - Biotechnology Option; Doctor of Philosophy in Chemistry - Biochemistry Option (through a joint program with the Department of Chemistry- see description in Chemistry section).

A Graduate Certificate in Biotechnology and Bioprocessing, offered by the Massachusetts Bioprocess Development Center, is administered jointly by the Departments of Biological Sciences and Chemical and Nuclear Engineering (more information follows the degree program descriptions).

Research and Teaching Facilities

The Departmental research and teaching instrumentation includes an array of centrifuges (ultraspeed, superspeed, microfuges), electrophoresis equipment (prep and analytical for proteins and nucleic acids, sequencing, isoelectric focusing, pulsed-field), PCR thermal cyclers, HPLC perfusion and other chromatography equipment; UV-visible and fluorescence spectrophotometers, scintillation spectrometers, various microscopes (transmission EM, fluorescence, inverted phase), microinjection apparatus, flow cytometer, Coulter counter, speed vac, electroporator, microtiter plate reader, fermenters, laminar-flow hoods, and numerous incubators, baths, and ovens for cell growth and temperature-controlled reactions. The facilities include dark rooms, X-ray facility, temperature-controlled plant and animal cell culture incubation chambers and walk-in rooms, and animal quarters. Labs and offices have Internet access and extensive computer facilities such as computerized image processing and microdensitometry. Highly specialized equipment in the Center for Advanced Materials in the Chemistry Department, such as transmission and scanning electron microscopes, scanning tunneling-atomic force microscope, secondary ion mass spectrophotometers, and X-ray diffractometers, are available for faculty and student research.

Faculty Research Interests

The graduate faculty in the Department of Biological Sciences are actively engaged in research in the following areas: biochemistry, molecular biology, cell biology, immunology, neurobiology, developmental biology, tumor cell biology, and applied and environmental microbiology.

MASTER OF SCIENCE DEGREE PROGRAMS

The Master of Science in Biological Sciences and the Master of Science in Biological Sciences - Biotechnology Option provide the advanced study and training necessary to conduct independent research at a professional level and to be successful in today's competitive academic and industrial research markets. Students in the program will be encouraged to explore quantitative approaches to the solution of problems in the basic and applied biological sciences. Depending on their career goals, students may choose either research or course work options within the Department, or from the interdisciplinary Biotechnology option. All candidates for the master's degree are expected to demonstrate sufficient knowledge and skills to pursue independent and creative research activities.

Entrance Requirements and Procedures

Entering graduate students are expected to have a sound preparation in the biological sciences, chemistry, physics, calculus, and statistics. A student found deficient in any of these areas may be required, during the first year, to take appropriate courses to eliminate the deficiencies. If the student has not had a biochemistry course, 81-519 should be taken for graduate credit. The departmental Graduate Coordinator helps plan the entering students' programs of study, acquaints them with research opportunities in the department, and assists in selecting research advisors.

Degree Requirements

A minimum of 30 semester hours of graduate level work is required for the Master of Science degree in Biological Sciences. The student has a choice of three options: thesis, project, or non-thesis. Minimal core requirements for all options include 2 semesters (4 credits) of Current Literature in Biology and 12 credits of formal course work selected from departmental electives (exclusive of thesis, project, problems, or other directed studies). The remaining 14 credits may be satisfied by additional electives within the department (thesis, project, problems, or more course work), by transfer credit for approved graduate level biological sciences courses taken at other accredited institutions (12 credit maximum), or by graduate courses taken in related disciplines within the University (e.g., chemistry, environmental sciences, chemical engineering, radiological sciences; 8 credit maximum). There is no formal language requirement. Students whose professional goals are to continue on for the Ph.D. degree, or who plan to seek employment in academic or industrial research laboratories as technicians or junior scientists are strongly advised to choose the thesis or project option in order to successfully compete for such positions. Students in the non-thesis option should endeavor to select courses with accompanying laboratories whenever possible.

Thesis Option

In choosing this option, the student concentrates on an in-depth, independent, scholarly investigation of a contemporary biological problem. Credit is allowed for 6-12 semester hours of M.S. Thesis Research. After consulting with the research advisor, the student selects two additional faculty members (one of whom must be from within the Department) to serve as members of the Thesis Committee. The student presents to the Committee a proposal of intended research and obtains the Committee's approval of the research topic. After completing the written thesis, the student gives an oral presentation of his results to the Thesis Committee.

Project Option

The project option is designed for independent laboratory investigations of a more limited nature than the thesis option. Generally, a project is completed in one or two semesters and credit is given for 3 or 6 semester hours of M.S. Project (no more than 6 credits will be allowed).

Non-Thesis Option

This option offers course work in breadth and depth, and may be of special interest to secondary school science teachers and individuals already employed in academic, hospital, or industrial laboratories. The non-thesis option may be completed during the day on a full-time basis or in late-afternoon or evening sessions on a part-time basis. However, since not all day courses are

available in the evening sessions, a part-time student's progress toward the M.S. degree will depend not only on his/her available time and abilities, but also on the scheduling of electives. In some instances, with the consent of a faculty member, an evening student may elect the thesis or project option.

Professional Experience

Credit (81-500; 3cr) may be requested by individuals who present satisfactory evidence (in the form of a written statement from their supervisor) of having at least one year of full-time experience in secondary school science teaching, or in an academic, hospital, or industrial laboratory setting.

Current Literature in Biology

Each student is required to complete 2 semesters of Current Literature in Biology.

M.S. IN BIOLOGICAL SCIENCES - BIOTECHNOLOGY OPTION

This option is more structured than the M.S. in Biological Sciences program described above. The core curriculum offers extensive hands-on experience in current techniques and instrumentation. Field trips and seminars afford students an opportunity for interaction with the biotechnology industry. Students are encouraged to conduct research in one of the recognized areas of biotechnology or to present an innovative application of technology or engineering principles to a biological problem of economic interest. The nature and extent of the investigation will determine its degree credit value. Those who enter the program having already completed some of the core courses, or who already have extensive laboratory experience, may consult with an advisor to design a course of study appropriate to their needs. A variety of biotechnology-related electives are available.

Core Requirements Biotechnology Option

81.519	Biochemistry I
81.520	Biochemistry II
81.521	Techniques in Biochemistry
81.567/569	Recombinant DNA Techniques (lecture and lab)
81.576/578	Cell Culture (lecture and lab)
81.593/595	Immunology (lecture and lab)
81.706	Current Literature in Biology

Recommended Electives- Biotechnology Option

81.535	Principles of Cell and Microbe Cultivation
81.546	Isolation and Purification of Biotech Products
81 555	Biopharmaceutical GMP and Licensing
81.558	Industrial Microbiology
81.572/574	Virology Lecture and Lab
81.586	Biotechnology Processing Projects Laboratory
81.733	M.S. Project in Biology

Courses from other Departments may be elected with permission of the Biological Sciences Chairman or Graduate Coordinator. The sum of core and elective courses must total at least 30 credits.

FIVE YEAR B.S./M.S. PROGRAM

Outstanding undergraduates may pursue an accelerated five-year course of study leading to the B.S. and M.S. degrees in Biological Sciences. See description at the front of this catalog for further information.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM (PH.D IN CHEMISTRY-BIOCHEMISTRY OPTION)

The Department of Biological Sciences and the Department of Chemistry have developed a program in Biochemistry which results in the award of a Ph.D. in Chemistry. For a full discussion of program requirements please see the section on Biochemistry under the Chemistry section of this catalog.

GRADUATE CERTIFICATE IN BIOTECHNOLOGY AND BIOPROCESSING

This graduate certificate is offered jointly by the Department of Biological Sciences and the Department of Chemical and Nuclear Engineering. The Certificate is aimed at students who hold a baccalaureate degree in science, engineering, health, or related disciplines. It may also be attractive to a person currently enrolled in a graduate degree program, as well as to someone holding a master's or doctoral degree who wishes to add or enhance his or her competency in biotechnology and bioprocessing, but does not wish to take another advanced degree. The core sequence of courses emphasizes biological and engineering principles, process concepts and the application of these to process design and improvement. The lecture and laboratory approach is supplemented by case studies and design projects that teach specific principles. Individual courses deliberately cross disciplinary barriers. This allows those with a background in the sciences to gain facility with the engineering approach to problem solving, and permits engineers to learn and apply biological principles. Concurrently, participants learn teamwork in a multidisciplinary environment and practice a result-oriented, document-driven approach to efficient project completion.

The Certificate is composed of four core courses specified below. The fourth course may be chosen from a list of eligible options and the selection requires the approval of the program advisor. Certificate requirements involve completion of the four courses with a 3.0 average and no more than one course with a grade of C. The four course program must be completed within a 5 year period. The core courses are offered at convenient times in order to minimize conflict with regular work schedules.

Applicants will be considered following receipt of an application form available through the Graduate School. Applicants not presently matriculated must submit an official transcript demonstrating completion of a bachelor's degree in science, engineering, or a related discipline. There is no GRE or language requirement.

The courses for the Certificate may be used toward a graduate degree in either Biological Sciences or Chemical and Nuclear Engineering subject to the approval of the graduate coordinator. A grade of B or better is required for use toward a graduate degree. Qualified students may thus count the four core courses toward both the Graduate Certificate and a graduate degree.

Required Courses:

1. Principles of Cell and Microbe Cultivation (81.535/10.535)
2. Isolation and Purification of Biotech Products (81.545/10.545)
3. Biotechnology Processing Projects Laboratory (81.586/10.586)
4. One course from the list below, or another with permission of the department's program advisor.

Approved courses:

81:542, 555, 558, 567/569, 572/574, 576/578, 593/595

10:516, 518, 522, 528, 530, 555

Titles and descriptions of 81-prefix courses are listed below. For titles and descriptions of 10-prefix courses see the appropriate section of the Graduate Catalog under Department of Chemical and Nuclear Engineering.

COURSE DESCRIPTIONS

81.500 Professional Experience (3-0)3 Credits will be given to individuals who present evidence of having at least one full year of experience in an academic, hospital, or industrial laboratory setting, or in secondary school science teaching.

81.501, 502 Selected Topics in Biology (3-0)3, (3-0)3 Current topics in various fields of biology presented in lecture, seminar, or discussion groups. Subject matter varies depending on interests of instructors and needs of students. May be repeated for credit when course content differs. Recent offerings have included photobiology and photoreceptors, endocrinology, hormones and receptors, protein biochemistry, industrial cell culture, readings in advanced pathophysiology, and experimental hematology.

81.535 Principles of Cell and Microbe Cultivation (3-0)3 An in-depth examination is made of microbial and mammalian cell cultivation and concomitant production of commercially important products. Systems studied include the use of recombinant and nonrecombinant microbes and mammalian cells to produce proteins, antibiotics, vaccines and other bioproducts having therapeutic, diagnostic, or other commercial significance. Topics run from initial choice of producer through scaleup.

81.541 Advanced Topics in Cell Biology (3-0)3 Prerequisite: Biochemistry.
A seminar-format course that examines detailed aspects of various topics in cell biology including cell signalling, signal transduction, cytoskeleton, protein interaction and modifications, cell division, and the extracellular matrix. Introductory overview lectures will be expanded on by critical examination of recent publications. Students will give a 30 min. comprehensive presentation on current developments in an area of their choice subject to instructor approval. Prior courses in biochemistry and cell biology are strongly recommended as we will focus on advanced aspects rather than basic.

81.542 Cell Biology (3-0)3 Prerequisite: Biochemistry Ultrastructure and biochemistry of eukaryotic cells: cell membranes and organelles; energy capture and transduction; histochemical and biochemical studies of organelles at the optical and electron microscopic level; cytogenetics; brief discussion of prokaryotic cells. A substantial library investigation is required.

81.545 Isolation and Purification of Biotech Products (3-0)3 This course examines the efficient isolation and purification of biological products, especially proteins, from complex natural mixtures. Material is presented in a lecture and case-study format using purification and formulation of specific biomolecules. Students work in teams on design projects.

81.519 Principles of Biochemistry I (3-0)3 Prerequisite: Organic Chemistry (Physical Chemistry is recommended). Primarily for M.S. students in Biological Sciences. Lectures and text assignments on the subjects of protein, carbohydrate, lipid, enzyme and membrane biochemistry will be supplemented with research journal readings.

81-520 Principles of Biochemistry II (3-0)3 Prerequisite: 81-519 or equivalent. This course is a continuation of 81-519 and will include discussions on all aspects of amino acid and nucleic acid metabolism and protein biosynthesis.

81.521 Techniques in Biochemistry (1-4)2 Prerequisite/co-requisite: Biochemistry Required of M.S. students in the Biotechnology Option. Emphasis on common techniques and instrumentation employed in modern research laboratories.

81.555 Biopharmaceutical GMP and Licensing (3-0)3 This course examines how "drugs", "biologics" and "cellular therapies" are evaluated, manufactured and sold in the United States. cGMP's, clinical trials, INDA, NDA, ANDA, PLA, ELA, validation, Q.A., Q.C., interactions with FDA staff and with company product and process development, regulatory affairs, drug metabolism, medical affairs, and production are covered in a lecture and project format.

81.558 Industrial Microbiology (3-0)3 Selected topics concerned with the use of microorganisms for the production of substances of economic importance. The principles and techniques of fermentation to produce such products as amino acids, antibiotics, vitamins, and organic acids are addressed, with emphasis on metabolic regulation of biochemical pathways and genetics of industrially important microorganisms.

81.563 Electron Microscopy - Theory and Practice (2-6)4 Prerequisites: Biochemistry and permission of instructor. Introduction to electron optics and electron microscopes. Preparation of biological samples for electron microscopy. Operation of electron microscopes. Project required of all students.

81.567 Recombinant DNA Techniques (3-0)3 Prerequisites: Genetics, Biochemistry Co-requisite: 81-569. A study of the principles and specialized techniques of cloning, purifying, and manipulating recombinant DNA molecules. A term paper or seminar may be required.

81.569 Recombinant DNA Techniques Laboratory (1-4)2 Co-requisite: 81.567, permission of instructor. Laboratory experiments and independent projects designed to illustrate current techniques and instrumentation used in genetic engineering. Included are restriction digestion and mapping, cloning, plasmid purification, Southern blotting, PCR, and DNA sequencing. Students use various computer software programs for restriction digest and DNA sequence manipulation and analysis, and graphic presentation of recombinant constructs.

81.572 Virology (3-0)3 Prerequisites: Genetics and Biochemistry. A study of bacterial, animal, and plant viruses, including viral structure, modes of replication, biochemistry of the infected cell, genetic properties, and viral oncogenesis. Emphasis is on virus-cell interaction at the molecular level. A term paper or seminar is required.

81.574 Virology Laboratory (1-4)2 Experiments with bacterial and animal viruses include lytic virus propagation and titering, biochemical, biophysical, and genetic analysis of viral nucleic acids and proteins, and cell culture techniques.

81.576 Cell Culture (2-0)2 Prerequisites: Genetics, Biochemistry, Immunology Co-requisite: 81-578. Lectures and readings on the biology and culture of animal and plant cells in vitro, the specialized methodologies necessary for hybridoma technology, and the biotechnological applications of each of these areas. A term paper or seminar is required.

81.578 Cell Culture Laboratory (1-4)2 Co-requisite: 81-576 A series of exercises demonstrating the principles presented in 81-576. Techniques will include: media preparation, standard culture procedures and hybridoma methodology.

81.580 Developmental Biology (3-0)3 Prerequisites: Genetics, Biochemistry.
A study of the genes, growth factors and events which regulate the development of a fetus. The construction of the mammalian embryo is examined, from fertilization to birth. Lectures and original research papers are used to learn about cell fate determination, cell-cell interactions during organ formation, and the molecular biology of developmental processes.

81.586 Biotechnology Processing Projects Laboratory (2-3)3 This laboratory course examines bioprocessing, with emphasis on

techniques for the cultivation of cells, recovery and purification of cell products, biocatalysis, and analytical methods for the quantification of product yields.

81.593 Immunology (3-0)3 Prerequisites: Microbiology, Genetics, Biochemistry. A study dealing with the nature of the immune response with sections on antibody structure, function and production; antigen-antibody reactions; immunogenetics; and immune regulation, protection and injury.

81.595 Immunology Laboratory (1-4)2 A series of basic laboratory exercises dealing with the preparation, isolation and characterization of antigens, antibodies and effector cells. Semester project required.

81.706 Current Literature in Biology (2-0)2 Participants are required to present 2 seminars per semester: a short talk on an assigned journal article or topic, and a lecture-length presentation on an advanced topic or their own original research. A fully documented report must accompany the long seminar. Students are also graded on active participation in discussions and will critique each other's presentations.M.S. students are required to enroll twice for this course.

81.711,712 Graduate Topics in Biology (3-0)3, (3-0)3 Prerequisite: Graduate students only; permission of instructor. Selected topics and recent advances not covered in regular courses. Content varies from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary biology.

81.721, 722, 723 Problems in Biology (0-3)1 to (0-9)3 Prerequisite: permission of instructor Special research or laboratory projects, or extensive literature surveys, undertaken by the student to expand his/her knowledge in specific fields.

81.733,736 M.S. Project in Biology (0-9)3 or (0-18)6 An independent laboratory project which has been approved by a research advisor as a suitable subject for a Master's Project.

81-743,746,749 M.S. Thesis (0-9)3 to (0-27)9 An in-depth independent investigation of a problem which has been approved by the student's research mentor as a suitable subject for a Master's Thesis.

81.753,756,759 Ph.D. Dissertation (0-9)3 to (0-27)9 Thesis research by Ph.D. students who are in the joint Biochemistry Program Option (between the Chemistry and Biological Sciences Departments) and are conducting research with faculty in Biological Sciences.

DEPARTMENT OF CHEMISTRY

Department Chair

Edwin G.E. Jahngen
Professor; B.S., Bates College; Ph.D., University of Vermont.

Faculty

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The Department of Chemistry at the University of Massachusetts Lowell offers both the Master's Degree in Chemistry and the Doctor of Philosophy Degree in Chemistry. The Master's Degree is offered in the following specialties: Analytical, Biochemical, Inorganic, Organic, Physical and Polymer Chemistry. The Doctor of Philosophy Degree is offered in the specialties of Analytical, Inorganic, Organic and Physical Chemistry. In addition, the department offers the Doctor of Philosophy Degree with Options in Biochemistry, Environmental and Polymer/Plastics Engineering. These options allow interdisciplinary study and involve interaction between chemistry and other departments at the University of Massachusetts Lowell. Overall Departmental Entrance Requirements:

1. A Bachelor's Degree in Chemistry or a related discipline (which requires a solid base in Chemistry).
2. An Undergraduate GPA of 3.0 (or its equivalent).
3. A minimum combined score of 1500 on the GRE.
4. A minimum combined GRE Verbal and TOEFL of 1000 (for international students whose native language is not English).
5. Students not meeting these requirements are invited to enroll in the Graduate Certificate Program and retake these entrance exams.

MASTER OF SCIENCE DEGREE PROGRAM

Specializations are offered in biochemistry, analytical, inorganic, organic physical chemistry, and polymer science. This program provides opportunity for advanced study and research training in chemistry, both general and specialized. Provision also is made for the student to elect certain advanced subjects in related fields of mathematics, physics, and engineering.

Credit Requirements

A minimum of 30 credits is required for the Master of Science degree in Chemistry, with 18 credits being earned in courses; and 12 credits earned in graduate research and seminars. Of the 18 course credit minimum, exclusive of research and seminar, a minimum of 15 credits must be taken in chemistry. The remaining course credits (3 or more) may be taken in chemistry or in related fields such as physics, mathematics, biology or engineering. Credit normally is not allowed for 400 level subjects in chemistry except for those designated in the catalog or approved by a student's advisor. Each graduate program in chemistry must include at least three advanced subjects from three of the following areas: analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, physical chemistry, or polymer chemistry, unless such requirements have been met previously and approved by the department.

Requirements
Specialization in Analytical Chemistry

84.514 Advanced Analytical Chemistry

and two courses from the following selection:

84.523 OrganicReaction Mechanism
or
84.568 Structural Analysis
84.532 Advanced Physical Chemistry
84.550 Biochemistry I
84.543 Modern Inorganic Chemistry

Specialization in Biochemistry

84.550 Biochemistry
84.551 Biochemistry II

and any two courses from the following selection:

84.523 Organic Reaction Mechanisms
84.538 Biochemical Mechanisms
or
84.568 Structural Analysis
84.514 Advanced Analytical Chemistry
84.526 Chromatography
or
84.580 Advanced Analytical Biochemistry
84.532 Advanced Physical Chemistry
84.560 Advanced Physical Biochemistry

Specialization in Organic Chemistry

84.523 Organic Reactions, Mechanisms and Structure
84.524 Organic Synthesis
84.568 Structural Analysis

and at least two courses from the following selection:

84.532 Advanced Physical Chemistry
84.521 Physical Organic Chemistry
84.550 Biochemistry I
84.543 Modern Inorganic Chemistry

Specialization in Inorganic Chemistry

84.543 Modern Inorganic Chemistry
84.532 Advanced Physical Chemistry
84.523 Organic Reaction Mechanisms

and one course from the following

84.514 Advanced Analytical Chemistry
84.550 Biochemistry I
84.551 Biochemistry II

Specialization in Physical Chemistry

84.531 Statistical Thermodynamics
84.532 Advanced Physical Chemistry
84.513 Spectroscopy
84.523 Organic Reaction Mechanisms
84.543 Modern Inorganic Chemistry
84.540 Chemical Kinetics

Specialization in Polymer Science

Required:

97.601/602 Polymer Science Seminar
97.603/604 Polymer Science Colloquium

plus selections from the following courses:

97.503 Advanced Polymer Science I
97.505 Polymer Preparation and Characterization
84.568 Structural Analysis
97.553 Organic Chemistry of Macromolecules
84.532 Advanced Physical Chemistry
84.523 Organic Reaction Mechanisms

Seminar Requirement

Each semester the student is required to attend and participate in the chemistry seminar/colloquium program 84.601,602, 603 and 604. In addition, a master's candidate is required to present one seminar.

Thesis Advisory Committee

An advisory committee should be selected jointly by the student and advisor at the earliest possible opportunity. A minimum of three (3) faculty members are required for the master's thesis committee. The student's advisor will serve as the chairperson of this advisory committee. The purpose of this committee is twofold. First, it will be responsible for ascertaining that the student's research was conducted and presented in final form, in a professional and acceptable

manner. Perhaps of more importance, the committee will serve in an advisory capacity during the course of the research project. In this spirit it is recommended that the student convene a meeting of the selected committee prior to starting his/her research. The purpose of this meeting is to informally present an outline of the proposed research project.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM
Analytical, Inorganic, Organic and Physical Chemistry Specializations

The doctoral program in chemistry is designed to provide the students with a background in advanced course work and chemical laboratory techniques that will prepare them to carry out, under the guidance of experienced scientists, an original, independent investigation that will lead to an acceptable contribution to the body of contemporary knowledge.

Plan of Program

The doctoral degree normally requires four years of study beyond the bachelor's degree or a minimum of two to three years beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through a conference with the Advisory Committee (or with his or her temporary advisor).

The initial part of the student's program, normally completed at the end of two years of study, is devoted to formal course work. The first year is usually given to subjects in the major branches of chemistry in preparation for area (candidacy) examinations. The second year is devoted primarily to advanced subjects in a special field of concentration.

The second and final part of the program is devoted principally to research leading to the doctoral thesis. However, the student is encouraged to begin research as early as possible in the program of study.

Research Tools Requirements

Students in all Ph.D. programs must acquire facility in two research tools. These research tools may be a second foreign language, a computer language, a statistics course or other skill acceptable to both the Graduate Coordinator and the research advisor of the student. The language(s) selected may not include the native language of a student's country of origin. Outlined below are the pathways by which these requirements can be satisfied.

I. Completion of a Language Requirement.

Completion of a two-semester undergraduate course sequence in French, German, Japanese or Russian with an average grade of B or better satisfies this requirement. These courses may be taken at the University of Massachusetts Lowell or at another institution. The following courses at the University of Massachusetts Lowell are acceptable:
Scientific German I and II (51.113 & 51.114)
or
Intermediate German I and II (51.211 & 51.212)
or
Intermediate French I and II (50.211 & 50.212)

II. Completion of Research Tools Requirement

The following courses represent a selection from which a student may-choose a research tool:
92.263 Fortran Programming
92.265 Introduction to Pascal
92.383 Introduction to Statistics
92.386 Statistics for Science and Engineering
92.385 Biostatistics
84.529 Chemometrics - if 84.529 is chosen as a research tool, credit for this course can not count toward the 27 course credits needed. Students in Analytical Chemistry may not use this course as a research tool.

Credit Requirements

Of the 45 minimum credit requirements, a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with at least18 to be taken in chemistry. The remaining course credits (9 or more, with a student's Advisory Committee having the authority to add 6 additional credits to the minimum in special situations) may be taken in chemistry or in a related field such as biology, physics, mathematics or engineering. Credit is not normally allowed for undergraduate subjects in chemistry except for those so designated in the catalog. Research credits and seminars would then make up the remainder of the 45 credit requirements. Planning the program of courses with the student is the responsibility of a student's Advisory Committee.

Course Requirements

Each student in any of the Ph.D. programs in Chemistry shall take both an advanced course in Physical Chemistry and Organic Chemistry and two courses from Advanced Inorganic, Advanced Analytical, Biochemistry, or Polymer Chemistry unless such requirements have been met previously.

Since each division (Analytical, Biochemistry, Organic and Physical/ Inorganic) has its own specific course requirements, a student intending to specialize in one of these areas is encouraged to meet with the coordinator of the division.

A. Course Requirements (Ph.D.): Analytical Chemistry Specialization

1. 27 Credits in course work are required

2. Required Courses:
84.514 Advanced Analytical Chemistry
84.523 Organic Reaction Mechanisms
or
84.568 Structural Analysis
84.532 Advanced Physical Chemistry
84.543 Modern Inorganic Chemistry

Note: With the exception of 84.514, Advanced Analytical Chemistry, one of the following courses may be substituted for one of the above with the permission of the student's faculty advisor and the analytical coordinator.
84.538 Biochemical Mechanisms
84.550 Biochemistry I
97.511 Biopolymers

Of the remaining 15 credits at least 6 must be in chemistry. The approval of the advisor and analytical coordinator are required for non-chemistry courses. Such courses must be justified as being relevant to the student's course of study.

B. Course Requirements (Ph.D.): Inorganic Chemistry Specialization

Required Courses:
84.532 Advanced Physical Chemistry
84.543 Modern Inorganic Chemistry
84.534 Quantum Chemistry
84.540 Chemical Kinetics
84.523 Organic Reaction Mechanisms and Structures
One course to be selected from:

84.514 Advanced Analytical Chemistry
84.550 Biochemistry I
84.551 Biochemistry II

The remaining 9 credits may be taken in chemistry, mathematics or engineering.

C. Course Requirement (Ph.D.): Organic Chemistry Specialization

Required Courses:
84.515 Chemical Literature
84.523 Organic Reaction Mechanisms
84.524 Organic Synthesis
84.532 Advanced Physical Chemistry
84.568 Structural Analysis

Two courses selected from the following also are required:
84.514 Advanced Analytical Chemistry
84.534 Quantum Chemistry
84.538 Biochemical Mechanisms
84.543 Modern Inorganic Chemistry
84.550 Biochemistry I

The remaining course requirements may be fulfilled by selecting courses from the following list or from graduate courses offered by other departments.
84.516 Advanced Analytical Techniques
84.521 Physical Organic Chemistry
84.527 Stereochemistry
84.563 Chemistry of Natural Products
84.565 Heterocyclic Chemistry

D. Course Requirements (Ph.D.): Physical Chemistry Specialization

Required courses:
84.532 Advanced Physical Chemistry
84.523 Organic Reaction Mechanisms
84.543 Modern Inorganic Chemistry
and a choice from the following:
84.513 Spectroscopy
84.514 Advanced Analytical Chemistry
97.503 Advanced Polymer Science I

Written Area Examinations

Upon admission to the Ph.D. program the student must pass exams in his/her major area of specialization. The method of conducting these area exams is designated by the staff in each field of specialization, as follows:

Analytical Chemistry

The area examinations for analytical chemistry will consist of a series of six (6) examinations. The first will be a qualifying examination to determine if the student is prepared to take the remaining five area examinations. The student will have two opportunities to pass the qualifying examination, which will be administered at the beginning of the student's second and third semester of residence. The remaining five examinations will be offered annually, commencing in October and administered at monthly intervals. A minimum of 3.0 out of a possible 10.0 points is required for each individual examination and a total of at least 30.0 out of a possible 50.0 points is required for the successful completion of the Written Area Examination. Failure to perform adequately may result in the student being required to complete a master's degree. Continuation towards the Ph.D. degree will be considered on a case by case basis.

Inorganic Chemistry

The area examinations in Inorganic Chemistry will be a series of cumulative examinations. The student is expected to begin the series of exams in the second year of study. The area examinations will consist of a series of five (5) examinations. The examinations are each graded from zero to a maximum of three points. A student must receive a total of eight (8) points to successfully complete the area examinations. Students who do not receive the necessary points may complete a master's degree and with special permission apply for readmission to the Ph.D. program in Inorganic Chemistry.

Organic Chemistry

Organic students take a series of eight cumulative examinations, given once a month (except December), beginning in September of each year. The examinations are graded pass or fail and a student must pass four of the examinations. The examinations must be taken in consecutive months. Typically, a student will start the examinations in the second year of graduate study and must complete these examinations by the end of the third year of graduate study.

Physical Chemistry

By the third year of graduate study, a Ph.D. student in physical chemistry must take a comprehensive examination. This is an all day written examination with questions designed to test the student's physical chemistry background, and ability to set up models and solve them mathematically. The student has two chances to pass the comprehensive examination.

Research Proposal

As part of the area examination(s) a Ph.D. candidate must present an oral defense of an original research proposal within 6 months of completing the written area examinations although a specific program may require the proposal to be presented at an earlier date. With the aid and advice of the Advisory Committee the student selects a suitable subject for investigation, completes a literature survey, outlines the method of approach, and suggests possible results and conclusions. The oral defense of this proposal is conducted by the student's Advisory Committee with other faculty members in attendance. The proposal is defended by the end of the semester following completion of area exams. The topic of the proposal can not be closely related to or contained within the thesis project.

Chemistry Seminar

During each year of residence the student is required to attend and participate in 84-601,602, Chemistry Seminar, and 84-603,604, Chemistry Colloquium. Each doctoral student is required to present two seminars.

Candidacy for the Doctorate in Chemistry

To be admitted to candidacy for the doctorate, a student must:

1.Satisfy the 27 course credit requirement, with a minimum Grade Point Average of 3.0.

2. Pass the area examinations, which includes completion of a research proposal.

3. Fulfill the research tools requirements.

4. Inform the graduate coordinator that the above requirements have been completed.

Ph.D.OPTION IN BIOCHEMISTRY

The Departments of Chemistry, Health and Clinical Sciences and Biological Sciences have developed a program in biochemistry which results in the awarding of a Ph.D. in Chemistry.

This program draws upon the special and diverse talents of these faculties, and provides chemistry graduate students with both in-breadth class work and in-depth thesis research. Emphasis is on the application of modern techniques and concepts of physical and chemical science to the solution of problems of current interest in biology and medicine.

Students may choose one of four concentrations in the Biochemistry Option:

1) Biochemistry
2) Bioprocessing
3) Biological Sciences
4) Clinical Chemistry

Dissertation research can be conducted in any of the aforementioned departments or in an interdisciplinary setting.

Admission Requirements and Removal of Undergraduate Deficiencies

Admission to the program requires demonstration of an acceptable B.S.,B.A., or M.S. degree in chemistry, biology, biochemistry or other related science. Students will be expected to have completed two semesters each of general, organic and physical chemistry as well as introductory biology. Deficiencies must be removed by enrolling in the corresponding undergraduate course during the first year in the program.

Academic Standards for Retention in the Biochemistry Program

The graduate student is expected to maintain an average of 3.0 or better in all his/her graduate-level courses. All other department requirements must also be met.

Research Tools Requirement

These requirements have been previously described.

Degree Requirements

There are 45 credits required for the Ph.D. in Chemistry, Biochemistry Option. A total of 27 of these must be in formal courses while the remaining 18 will be accrued in Doctoral Dissertation. Of the 27 required hours of graduate course work, the Biochemistry Program requires that 15 hours are in the specific courses delineated below:

84.550 Biochemistry I
84.551 Biochemistry II
84.538 Biochemical Mechanisms
84.560 Advanced Physical Biochemistry
84.580 Advanced Analytical Biochemistry

The remaining courses (a minimum of 12 hours) may be selected from approved graduate courses in the Biology, Chemistry or Clinical Lab Sciences Departments. Course selection should be made in consultation with the advisor. Below is a list of suggested courses.

36.506 Biochemistry of Lipids
36.550 Human Development and Pathophysiology
36.551 Advanced Pathophysiology
36.552 Advanced Clinical Biochemistry
81.525 Neurobiology
81.535 Principles of Cell and Microbe Cultivation
81.545 Isolation and Purification of Biotech Products
81.567/569 Recombinant DNA Techniques
81.576/578 Cell Culture and Hybridoma
81.580 Developmental Biology
81.593/595 Immunology
84.514 Advanced Analytical Chemistry
84.526 Chromatography
84.543 Modern Inorganic Chemistry
84.563 Chemistry of Natural Products

Seminars

During each semester in residence all full-time students must register for a seminar course and attend one seminar each week, as required by the Chemistry Department. The student is required to present two one-hour presentations during his/her residence.

Research

A. Initiation of Research - Preceptor Selection Procedure.
The dissertation research of each graduate student may be initiated at any time but not later than the end of the second semester in the program. The student is advised to make serious efforts, prior to the summer following his/her first entrance to the program, to initiate faculty research interviews and attempt to identify the area of his/her research interest and particular research group which may be suitable for pursuing his/her research goals.

B. Examination Committee.
The examination committee will be composed of four faculty members chosen after consultation by the student with his/her preceptor. Two of these members must be from the Department of Chemistry faculty.

Examinations

A. Comprehensive Examination.
Please contact the biochemistry graduate coordinator concerning details about the comprehensive examination.

B. Oral Research Proposal. Prior to the end of the 4th semester of matriculation, the student will be required to present and defend, orally, a research proposal in an area of biochemistry related to but not identical to that of his/her thesis. A written copy of the proposed research must be distributed to the Examination Committee at least one week prior to the examination. All members of the university community are welcome to attend these examinations. Failure to perform adequately in either the written proposal or the oral defense may result in the student being required to complete an M.S. degree. Continuation toward a Ph.D. degree will be judged on a case by case basis.

Admission to Candidacy for the Doctorate

To be admitted to candidacy for the doctorate, a student must:
1. Complete all required courses with necessary grade point average. There is an absolute minimum cumulative grade point average (GPA) requirement of 3.0 for all graduate work. At the end of the first semester, if a student is found to be below the minimum GPA, a written warning will be issued. If the cumulative GPA is not raised to 3.0 or higher by the end of the second semester in residence, the student will automatically be dropped from the Ph.D. program but allowed to continue toward a master's degree in Biochemistry with the approval of the graduate committee. While completing the M.S., a candidate must have a minimum GPA of 3.0 and maintain that GPA throughout the remainder of his or her career. Upon successful completion of the Master of Science degree, the student may reapply for admission to the doctoral program. Each case will be reviewed on an individual basis by the Biochemistry Graduate Committee. Students reentering the Ph.D. program will then satisfy all the requirements for the degree including passing the comprehensive examination, presentation of their research proposal, and completion of their research and dissertation defense. Seminar presentations and course work accomplished to complete the master's degree will, of course, be cumulative.
2. Pass the Comprehensive Examination given at the beginning of the fourth semester of full time study.
3. Fulfill the research tools requirement.
4. Successfully present and defend the Oral Research Proposal by the end of the fourth semester of full time study.
5. Present two seminars.
6. Secure approval of his/her research preceptor and the biochemistry committee. When these requirements have been fulfilled, the Biochemistry Graduate Committee will recommend that the

graduate coordinator of the Department of Chemistry notify the Dean of the Graduate School to place the student on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

PH.D. OPTION IN ENVIRONMENTAL STUDIES

This graduate program is designed as an optional course of study to the traditional Ph.D. in Chemistry for students with backgrounds in engineering (civil, environmental and chemical engineering) and other sciences (physics, biology, etc.) as well as chemistry. Candidates will be exposed to advanced course work in chemistry and environmental engineering and will be able to choose an area of specialization that best suits their interests and previous experience. A combination of faculty from Chemistry, Work Environment and Civil Engineering with a variety of research expertise gives this program unique characteristics and affords the student the opportunity to perform practical interdisciplinary research. It is expected that most students will require at least four years beyond the Bachelor's degree and two years past the Master's degree.

Entrance Requirements

In addition to the requirements for admission listed in this catalog, applicant will have an earned bachelor's degree in one of the following fields: chemistry, chemical or civil engineering, biology, environmental sciences, geology or physics. Students will be expected to have satisfactorily completed undergraduate courses in analytical, organic, and physical chemistry, physics and calculus. However, applicants who have not completed courses in these areas of chemistry may remedy their deficiencies while in the program and,therefore, are encouraged to apply. Admissions will be determined by a committee consisting of faculty from the Chemistry, Work Environment, and Civil Engineering Departments.

Program Outline

A total of 48 credits are required for the Ph.D. program. Of these, at least 30 credits must be in course work exclusive of seminar and the rest is usually in thesis research. Courses shown below are divided into three categories: core course requirements (9 credits), areas of specialization (12 credits), and elective courses (9 credits). Additional elective courses from other departments may be substituted with the approval of the student's Advisory Committee. In addition, full-time students must register for 84.601/84.602 or 18.502 Environmental/ Analytical seminar every semester. Each student will be required to give two seminars on current research topics during their graduate career. Students in the Environmental program must select a thesis advisor by the end of the second semester. At this time, an Advisory Committee is appointed and a plan of study is established. The Advisory Committee must consist of at least four members, including the thesis advisor. A minimum of two chemistry department faculty are required to be on the committee with two other members from any participating Department. An additional member from another department may also be added if agreed upon by the student and thesis advisor. Students must maintain a 3.0 cumulative average in order to continue in the program.

Required Courses (21 credits):

I. Core Courses (9 credits)
84.514 Advanced Analytical Chemistry
84.532 Advanced Physical Chemistry
or
84.575 Physical Chemistry for Environmental Studies
84.523 Organic Reaction Mechanism
or
84.568 Structural Analysis
II. Areas of Specialization (12 credits)
a. Analytical /Environment
14.567 Environmental Chemistry I (Aquatic Chemistry)
14.568 Environmental Chemistry II (Fate and Transport)
84.519 Environmental Chemistry III (Marine Chemistry)
84.526 Chromatography
b. Water Environment
14.567 Environmental Chemistry I (Aquatic Chemistry)
14.568 Environmental Chemistry II (Fate and Transport)
84.519 Environmental Chemistry III (Marine Chemistry)
14.562 Groundwater Hydrology
c. Air Environment
18.571 Air Pollution Phenomenology
18.523 Air Resources Management & Control
18.573 Air Pollution Laboratory (Monitoring and analysis)
14.568 Environmental Chemistry II (Fate and Transport)
III. Elective Courses (9 credits)
84.575 Physical Chemistry for Environmental Studies
84.532 Advanced Physical Chemistry
84.523 Organic Reaction Mechanisms
84.568 Structural Analysis
14.567 Environmental Chemistry I (Aquatic Chemistry)
14.568 Environmental Chemistry II (Fate and Transport)
84.519 Environmental Chemistry III (Marine Chemistry)
84.526 Chromatography
84.564 Spectrochemical Analysis
14.562 Groundwater Hydrology
14.561 Physical Chemical Treatment Processes
18.568 Environmental Laboratory
18.571 Air Pollution Phenomenology
18.523 Air Resources Management
18.573 Air Pollution Laboratory (Monitoring and Analysis)
93.415 Advanced Atmospheric Dynamics I
93.416 Advanced Atmospheric Dynamics II
93.430 Atmospheric Diffusion
18.572 Energy and the Environment
92.591 Statistical Modeling and Data Analysis
14.565 Industrial Waste Water Treatment Processes
18.510 Water Resources Management
18.522 Solid Waste Management (Municipal, Industrial and Hazardous)
18.525 Epidemiology for Environmental Studies
18.527 Environmental Law
19.501 Industrial Hygiene
81.xxx Wetlands Ecology
84.515 Chemical Literature
98.501 Radiation Safety and Control
98.503 Radiation Biology
98.508 Environmental Toxicology

Written Area Examinations (Cumulative Examinations)

Beginning in the second year of study, the student must pass examinations in their major area of specialization. The examinations are administered by the faculty associated with the program and are based on course work either completed or in progress as well as seminars, scientific literature and accepted theory in the field of study. Environmental studies students take six cumulative examinations each of

which focuses on a different area of environmental science and analytical chemistry. Students must take the examinations consecutively in a given academic year. The topic, date, time and faculty member in charge of a particular exam in the cumulative examination series will be given to the student prior to the first cumulative exam. Students taking cumulative exams are urged to meet with the individual faculty member preparing an exam for more specific information. If a student misses a cumulative exam a grade of zero will be assigned. There are no makeup cumulative exams.

Research Proposal

A Ph.D. candidate must submit an original research proposal and successfully pass an oral defense of that proposal in their second or third year of study. After consulting with their Advisory Committee, the student selects a suitable subject for investigation, completes a literature survey, outlines the method of approach, and suggests possible results and conclusions. The oral defense of this proposal is conducted by the student's Advisory Committee with other faculty in attendance. The proposal must be defended within three months following completion of the cumulative examinations.

PH.D.OPTION IN POLYMER SCIENCE AND POLYMER SCIENCE/PLASTICS ENGINEERING

Students in the Ph.D. Program in the Department of Chemistry may elect the Polymer Science or the Polymer Science/Plastics Engineering Option. The Polymer Science/Plastics Engineering Option doctoral program is organized jointly with the Department of Plastics Engineering. The program is designed to provide students with a background in advanced course work and laboratory techniques that will prepare them to carry out an original investigation leading to an acceptable contribution to the body of contemporary knowledge in the fields of macromolecules or plastics.

Plan of Program

The doctoral degree normally requires four years of full-time study beyond the bachelor's degree or a minimum of two to three years of full-time study beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through conference with his/her Advisory Committee (or temporary advisor).

All students entering the program must take the American Chemical Society Graduate Level placement examinations in organic, physical and analytical chemistry. An evaluation examination in polymer science is given to those who wish to be exempted from 97-503-504.

Requirements for Admission

Requirements for admission into the program are the same as those for students entering other Ph.D. programs in Chemistry. It is the student's responsibility to satisfy any admission requirements stipulated for the Ph.D. in Chemistry.

Undergraduate deficiencies in the student's background must be remedied promptly, usually by the end of the student's second semester. During this period, the student must also successfully complete graduate courses appropriate to his/her background. Students will not be formally admitted to the Ph.D. program if their grade point average is below B.

Course Requirements

Of the 45 minimum credit requirements a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with at least four courses to be taken in chemistry and polymer science (84 and 97 prefixes). The remaining course credits may be taken in chemistry or in the courses listed below. Credit normally is not allowed for undergraduate subjects in chemistry except for those so designated in the catalog. Research credits (18) would then make up the remainder of the 45 credit requirement. The program of courses is the responsibility of a student's Advisory Committee and must include advanced subjects in the appropriate areas of chemistry, polymers, and plastics. When it is necessary to carry less than the normal credit load of 9 per semester, the student must apply to the chairman of the department through the chairman of his/her Advisory Committee for approval.

Required Courses

The student must take the following core courses: Polymer Science:

84.523	Organic Reaction Mechanisms
84.568	Structural Analysis
84.532	Advanced Physical Chemistry
97.503	Advanced Polymer Science I
97.504	Advanced Polymer Science II
97.553	Organic Chemistry of Macromolecules
97.505	Polymer Preparation & Characterization I
97.506	Polymer Preparations & Characterization II
97.512	Bulk Properties of Polymers or
26.503	Mechanical Behavior of Polymers
26.506	Polymer Structure
26.509	Plastics Processing I
26.510	Plastics Processing II

Polymer Science/Plastics Engineering Option:

84.523	Organic Reaction Mechanisms
or	
84.568	Structural Analysis
84.532	Advanced Physical Chemistry
97.503	Advanced Polymer Science I
97.504	Advanced Polymer Science II
97.553	Organic Chemistry of Macromolecules
97.505	Polymer Preparation & Characterization I
97.506	Polymer Preparations & Characterization II
97.512	Bulk Properties of Polymers
or	
26.503	Mechanical Behavior of Polymers
26.506	Polymer Structure
26.509	Plastics Processing Theory I
26.510	Plastics Processing Theory II

The following course schedule is suggested to prepare the students for the cumulative examinations: First Semester

97.503	Advanced Polymer Science I
or	
26.503	Mechanical Behavior of Polymers
26.509	Plastics Processing Second Semester
97.503	Advanced Polymer Science II
97.553	Organic Chemistry of Macromolecules
97.510	Plastics Processing II Third Semester
97.505	Polymer Preparation & Characterization

In addition, the student must register for Polymer Seminar 97.601/602 and 97.603/604 Polymer Science Colloquium each semester.

Advisory Committee

Upon admission the student will be assigned a temporary adviser by the Coordinators of the Graduate Polymer Program and Graduate Plastics Program. The student's major thesis adviser will become the chairperson of the permanent Advisory Committee.

For students who elect the plastics concentration, the permanent Advisory Committee will be composed of four members, two from theDepartment of Chemistry and two from the Department of Plastics Engineering. One of the committee members from the Chemistry Department will have the responsibility of advising the student in course work and research activities in the field of polymers.

The Advisory Committee will meet at least once each semester to monitorthe progress of the student's research.

Program Outline

The initial part of the program is devoted to formal course work. The first year usually is devoted to subjects in major branches of chemistry, polymers, and plastics in preparation for the student's area(cumulative) examinations. The student must choose a research adviserbefore the end of the second semester and is normally expected to start research during the first summer.

Research Tools

Pathways for satisfying these requirements have been described previously under the Chemistry section of this catalog.

Written Area Examinations

Upon formal admission to the Ph.D. program the student is required to pass a series of consecutive cumulative area examinations. This requirement must be completed by the end of the third semester for students entering in the fall semester, and by the end of the fourth semester for students entering in the spring semester. Policy and grading underlying each examination will be announced at the beginning of each academic year.

Each student must also present an oral defense of an original research proposal within six months after the completion of the last area exams.

Successful performance of an original research project, completion of a written dissertation and subsequent successful public presentation and defense of the dissertation research will culminate in granting of the Ph.D. degree in Chemistry.

Candidacy for Ph.D. Polymer Science/Plastics Engineering Option

To be admitted for candidacy for the doctorate, a student must:

1. Satisfy the 27 course credit requirement with a minimum gradepoint average of 3.0.
2. Pass the area examinations which includes completion of the research proposal.
3. Fulfill the language requirements.
4. Secure the approval of his/her Advisory Committee and the Graduate Coordinator of the Department of Chemistry.

When these requirements have been fulfilled, the Graduate Coordinator of the Department of Chemistry notifies the Dean of the Graduate School in writing and recommends that the student be placed on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

COURSE DESCRIPTIONS

84.513 Spectroscopy (3-0)3 Prerequisite: 84.431-432 or equivalent. A presentation of molecular spectra and molecular structure is given to illustrate the empirical results and the theoretical background necessary to interpret the results.

84.514 Advanced Analytical Chemistry (3-0)3 Prerequisite: 84-313 and 314 or the equivalent or the permission of Analytical Chemistry Faculty. This course is required of all students in the Analytical Chemistry and Ph.D. Environmental Studies Program. Principles of modern molecular Spectroscopy, and electroanalytical chemistry are covered. The course is designed to prepare a student for advanced courses in the area of Analytical Chemistry.

84.515 Chemical Literature (3-0)1 Use of the chemical library, journals, reference works and other technical publications pertaining to chemical subjects. Exercises in finding, assembling and using such data. The student will be expected to assimilate the use of automated information retrieval and conduct computer assisted literature searches.

84.516 Advanced Analytical Techniques (1-6)3 Prerequisite: Permission of Instructor A study of the theory and application of the more advanced techniques and equipment in the preparation and purification of organic compounds, including high efficiency fractionation, vacuum and molecular distillation, hydrogenation and reactions in inert atmosphere.

84.519 Environmental Chemistry (3-0)3 Prerequisite: Permission of Instructor. The chemistry of the oceans, atmosphere and biosphere source and removal mechanisms of natural and anthropogenic substances, thermodynamic and kinetic models in addition to instrumental analytical methods.

84.521 Physical Organic Chemistry (3-0)3 Prerequisite: 84.523, 524 or equivalent. Modern and classical methodology in the study of organic reactions. Linear free energy relationships, tracer methods, orbital symmetry and other selected topics will be covered.

84.523 Organic Reaction Mechanisms and Structures (3-0)3 Prerequisite: Permission of Instructor. Designed to provide insight into how reactions occur and how the reactions mechanism is studied. Emphasis is placed on bonding, substitution and elimination processes, stereochemistry, and conformational analysis.

84.524 Organic Synthesis (3-0)3 Prerequisite: Permission of Instructor. Mechanism, scope and limitations of important selected types of reactions, and designs of synthetic sequences. Emphasis is placed on reduction, oxidation, halogenation, alkylation, and acylation reactions.

84.526 Theory and Applications of Chromatography (3-0)3 Prerequisite: Permission of Instructor. Coverage directed to the performance of the packed and capillary column for gas chromatography and HPLC. Modern injection, detector and pumping systems used in chromatography are also discussed.

84.527 Stereochemistry (3-0)3 The fundamental concepts of optical and geometrical isomerism and the relationship of the stereostructures to the physical and chemical properties of organic compounds.

84.529 Chemometrics (3-0)3 This course is a presentation of mathematical techniques useful for evaluating chemical data. Topics addressed include: parametric statistics, ANOVA, regression analysis, optimization and pattern recognition.

84.531 Statistical Thermodynamics (3-0)3 Prerequisite: 84.432 or equivalent. Fundamentals of equilibrium statistical mechanics, classical and quantum statistics. Molecular theories of gases, crystals and liquids, with emphasis on chemical aspects. Electrolyte and non-electrolyte solutions, polymer and polyelectrolyte systems, chemical equilibria and reaction rate processes.

84.532 Advanced Physical Chemistry (3-0)3 Prerequisite: Permission of Instructor. Extension of introductory physical chemistry.

Emphasis is placed on quantum chemistry of atoms and molecules as well as on classical and statistical thermodynamics.

84.534 Quantum Chemistry (3-0)3 Prerequisite: 84.431 or equivalent. Principles and methods of quantum mechanics with special attention to chemical applications, such as electronic nature of atoms and molecules, vibrations and rotation of molecules, and interaction of radiation with matter.

84.535, 536 Advanced Topics in Physical Chemistry (3-0)(3-0) 6 Selected topics and recent advances in physical chemistry. Selection of topics is at the discretion of the instructor.

84.538 Biochemistry Mechanisms (3-0)3 Prerequisites: 84-551 or Permission of Instructor. Discussion of various biochemical reactions from the point or view of organic reaction mechanisms. Kinetics, coenzymes and methods of study of enzyme catalysis and mechanisms will be emphasized.

84.540 Chemical Kinetics (3-0)3 Prerequisite: 84.432 or equivalent. The theoretical and empirical treatment of chemical kinetic data as well as the methods of obtaining these data. Determination of the order of reactions, factors influencing rates, application of rate studies in establishing hypotheses for reaction mechanism, collision theory, and absolute rate theory.

84.543 Modern Inorganic Chemistry (3-0)3 Prerequisite: Permission of Instructor. Emphasis is placed on the theory of the chemical bond, bonding in complexes, coordination theory, spectroscopic methods, non-aqueous solvent systems.

84.544 Chemical Applications of Group Theory (3-0)3 Prerequisite: 84.334, 84.543 or equivalent. Properties of groups as applied to chemical systems. Development of the ligand field theory and prediction of electronic and vibrational-rotational spectra.

84.550 Biochemistry I (3-0)3 Prerequisite: Permission of Instructor. An advanced study of the structure and properties of proteins, nucleicacids, carbohydrates and lipids, including kinetics and mechanisms of enzyme action, and detailed description of metabolic pathways of carbohydrates.

84.551 Biochemistry II (3-0)3 Prerequisite: 84.550 or Permission of Instructor. A continuation of 84.550 with emphasis on metabolic pathways of lipids, aminoacids and nucleic acid, biosynthesis of proteins and selected topics in molecular biology and specialty areas of biochemistry.

84.560 Advanced Physical Biochemistry (3-0)3 Prerequisites: Biochem. I 84.550, and P. Chem. 84.334 or equivalent. Physical chemistry encompasses a group of principles and methods helpful in solving many different types of problems. This course will present selected principles of thermodynamics, kinetics, statistical thermodynamics and quantum mechanics as they are applied to biochemical systems. Various experimental techniques will be discussed in view of their importance in biochemical research.

84.563 Chemistry of Natural Products (3-0)3 Prerequisite: 84.568, or equivalent . An advanced subject covering the proof of structure of various types of natural products, approaches to the total synthesis of some and also the biosynthetic pathways.

84.565 Heterocyclic Chemistry (3-0)3 Prerequisite: Permission of Instructor. Classification, nomenclature, structure, synthesis and utility of the more important classes of heterocyclic compounds.

84.568 Structural Analysis (3-0)3 Prerequisite: Permission of Instructor. Practical application of instrumental data in the determination of the structure of organic compounds. Includes mass spectroscopy, ultraviolet spectroscopy, infrared spectroscopy and nuclear magnetic resonance spectroscopy.

84.575 Physical Chemistry for Environmental Studies (3-0)3 Prerequisite: 84.339 or 84.344, 345. This course covers advanced physical chemistry related to environmental systems and measurements. Topics include the fundamental aspects of solution thermodynamics, electrolytes and non-electrolytes, electrochemical theory, surface chemistry, gas laws, kinetics and spectroscopy.

84.580 Advanced Analytical Biochemistry (3-0)3 Prerequisites: 84.550 or Permission of Instructor. Analytical Biochemistry involves the separation, detection, and analysis of biological molecules. This course addresses advanced theory and applications of contemporary biochemical techniques and instrumentation. Topics covered include chromatographic and electrophoretic separation techniques, detection of biomolecules by spectroscopy and radiochemical methods, biological preparations, and structural analysis of biomolecules.

84.585 Nuclear and Radiochemistry (3-0)3 Prerequisite: Permission of Instructor. This course stresses the fundamentals of radioactivity, atomic nuclei, nuclear reactions, reactors and detection and measurement of radiation. Applications of material and anthropogenic radioactive tracers to oceanic and atmospheric studies are also presented.

84.586 Spectrochemical Analysis Prerequisite: Permission of Instructor. A study of the instrumentation, theory and practice of atomic absorption, emission, and fluorescence in flames, plasmas, and electrothermal atomizers. Application of these techniques for tracemetal analysis in complex samples.

84.587 Laser Based Analytical Methods Prerequisite: Permission of Instructor. A brief overview and introduction to the laser will be followed by the application of the laser in analytical chemistry. Topics covered will be atomic and molecular spectroscopy. A discussion of instrumentation, brief theory and selected results will be presented.

84.601,602 Chemistry Seminar (1-0)(1-0)2 Required of all graduate students. Presentation of current topics by graduate students.

84.603.604 Chemistry Colloquium (1-0)1 Required of all graduate students. Presentation of current topics by visiting scientists and staff.

84.651 Selected Topics in Chemistry(3-0)3 Prerequisite: Permission of Instructor. Advanced topics in various fields of chemistry. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary chemistry.

84.751 Advanced Projects in Chemistry (0-3)(0-3)2 Special projects laboratory undertaken by a student to expand his or her knowledge in specific fields not necessarily related to his or her thesis. Content of project and hours assigned must be approved by the Department Chairperson.

84.743 Master's Research 3 credits
84.746 Master's Research 6 credits
84.749 Master's Research 9 credits
84.753 Doctoral Research 3 credits
84.756 Doctorol Research 6 credits
84.759 Doctoral Research 9 credits

97.503 Advanced Polymer Science I (3-0)3 Prerequisite: Permission of Instructor. A study of the principles of condensation, free radical, ionic, coordination and ring-opening polymerization. The topics include the effect of polymerization techniques on reaction kinetics and molecular weight, and the evaluation of reactivity ratios in copolymerzation reactions.

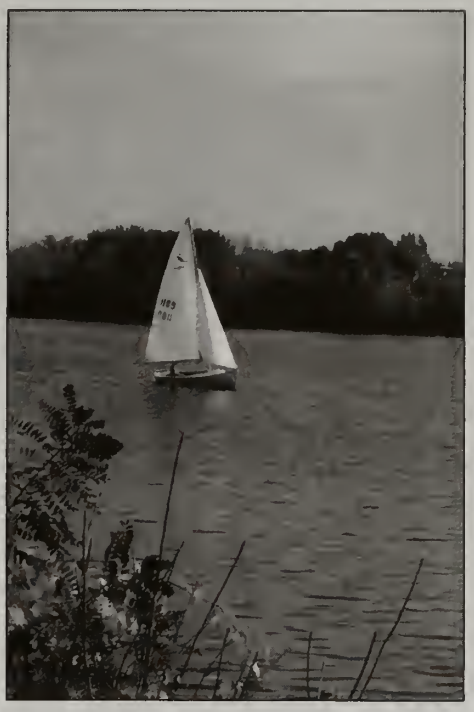
97.504 Advanced Polymer Science II (3-0)3 Prerequisite: Permission of Instructor. Introduction to chain statistics and thermodynamics of macromolecular solutions, methods of study of molecular weight and chain conformation, and the properties of polymers in bulk including viscoelasticity and crystallinity.

97.505 Polymer Preparation and Characterization (0-4)2 Prerequisite: Permission of Instructor. A laboratory course designed to acquaint the graduate student with the techniques used in the synthesis and characterization of macromolecules with the instrumental study of macromolecules by utilization of osmometry, light scattering, gel permeation chromatography, vaporpressure osmometry and infrared spectroscopy.

97.511 Biopolymers (3-0)3 Prerequisite: Permission of Instructor. Exploration of the synthesis, modification and properties of biologically derived macromolecules. Specifically, natural occuring polysaccharides, proteins, polyesters and nucleic acids will be discussed. An interdisciplinary approach between chemistry, polymer science and biology will be used in presenting the course material.

97.512 Properties of Bulk Polymers (3-0)3 Prerequisite: Permission of Instructor. Structure and properties of bulk polymers in the glassy, rubbery, and crystalline states. Topics covered include chain statistics, rubberelasticity, crystalline polymers, glass tran-

sition, segmental motion and viscoelasticity.
97.549 Physical Chemistry of Macromolecules I (3-0)3 Prerequisite: 97.503 or equivalent. Physical chemistry of polymers, including structure and conformation, chain statistics, molecular weight distributions and averages, polymerization kinetics and classical and statistical thermodynamics of polymer solutions.
97.553 Organic Chemistry of Macromolecules (3-0)3 Prerequisite: 97.503, 504. An advanced study in polymer science concerned with the synthesis ofmacromolecules and their mechanisms of formation.
97.601.602 Polymer Science Seminar (1-0)1 Required of all Polymer Science graduate students. Presentation of current topics in polymer science by graduate students.
97.603.604 Polymer Science Colloquium (1-0)1 Required of all Polymer Science graduate students. Presentation of current topics in polymer science by visiting scientists and staff.
97.651 Selected Topics in Polymer Science (3-0)3 Prerequisite: Permission of Instructor. Advanced topics in various aspects of polymer science. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge in the field of macromolecules.
97.751 Advanced Projects in Polymer Science (0-3)1 Special projects undertaken by a student to expand knowledge in a specific field not necessarily related to the thesis. Content of project and hours assigned must be approved by the Department Chairman.
97.753 Ph.D. Research in Polymer Science 3 credits
97.756 Ph.D. Research in Polymer Science 6 credits
97.759 Ph.D. Research in Polymer Science 9 credits



DEPARTMENT OF Computer Science

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Thomas Costello
Professor; B.S., Boston College; Ph.D., University of Maryland.

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Adjunct Faculty
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Gerry Pocock
Adjunct Professor; B.S., University of Rochester; M.S., Ph.D., University of Massachusetts Amherst.
Roy Rubenstein
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Adjunct Professor; B.A./B.S., University of North Carolina; M.S., University of Lowell; D.Sc., University of Massachusetts Lowell.
Linda Wilkens
Adjunct Professor; B.A., Framingham State College; M.S., Northeastern University; M.S., University of Lowell; D.Sc., University of Massachusetts Lowell.
Ifen Yang
Adjunct Professor; B.S., National Taiwan Normal University, Taipei; M.S., University of Lowell; D.Sc., University of Massachusetts Lowell.

The graduate program provides computer scientists with an education of sufficient breadth and depth to qualify them as leaders in both industrial and academic environments. It is distinguished by its emphasis on engineering aspects of computer science, with substantial exposure to the design and management of large software systems. This mission is supported by the University Center for Advanced Computation and Telecommunications, the Institute for Visualization and Perception Research, and the Multimedia Laboratory.

The program is intended primarily for students with undergraduate degrees in computer science, or for those who have completed a degree in a related area (Electrical Engineering, Mechanical Engineering, Mathematics, Physics, Management, etc.) and possess a substantial background in computer science. Recognizing the often interdisciplinary nature of computer science applications, the program features cooperation with allied departments in the Colleges of Arts and Sciences, Engineering, and Management. Students with strong interdisciplinary interests and abilities will be encouraged and advised on an individual basis.

Resources

The Computer Science Department has strong industrial ties through its faculty members, its participation in the work of various University Centers, its internal laboratories and institutes, its membership in the Massachusetts Microelectronic Consortium, its continuing relationships with all the major local computer and software manufacturers, and its industrial advisory committee. These are all sources for short and long range research projects, hardware donations, student funding, and direction.

To support instructional and research activities, the Department of Computer Science maintains a large heterogeneous network, including PCs, workstations, and a variety of other more specialized equipment. All systems are interconnected within the department and to the rest of the University via high-speed fiber-optic cabling. The University is a member of the Massachusetts Regents Computer Network, a network of all Massachusetts public universities and colleges. The Regents Network is a member network of the New England Academic and Research Network (NEARnet), which provides service to points around the world.

The Master of Science Degree Program

The Master of Science degree program in Computer Science serves several audiences,

from the professional with extensive industrial experience to the recent graduate aiming ultimately for an advanced research degree. In all cases, a major objective is to prepare the student for a work environment requiring continued growth.

The Doctor of Science Degree Program

The Doctor of Science degree program aims to provide a student, whether planning on an industrial or academic career, with a challenging research environment and the opportunity to tackle theoretical or applied projects of major scope, depth, and originality.

Graduate Certificate Programs

For students with appropriate backgrounds who need in-depth exposure to certain subfields of computer science or to certain computer science-related areas, the Department, in conjunction with other departments in the University, provides several graduate certificates. Admission to these programs requires demonstration of appropriate academic and professional background. Work completed within the scope of a graduate certificate can be used, when appropriate, towards a later Master's degree.

Admission Standards and Criteria
General Requirements

In addition to the requirements for admission listed on page 14 in this catalogue, applicants for admission to the graduate program at both the Master of Science and Doctor of Science level are expected to have an undergraduate degree in Computer Science or a related discipline such as Mathematics, Physics, or Engineering. They should submit the official application obtainable from the Graduate School. Besides undergraduate transcripts and letters of recommendation, applicants are expected to submit an official score from the Graduate Record Examination, with the general part required and the advanced computer science part recommended. Any student may be required, at the discretion of the department, to complete transitional or remedial courses without graduate credit.

M.S. Requirements

In order to be fully matriculated into the MS program, students must demonstrate competency in the following seven knowledge areas:

1. C or C++ programming and Data Structures
2. Discrete Mathematics
3. Calculus
4. Analysis of Algorithms
5. Programming Languages
6. Computer Architecture
7. Operating Systems

Competency is typically demonstrated either by producing a transcript of previous academic experience which contains passing grades in courses related to these seven areas, or by earning a C or better in the courses below. Competency can also be demonstrated by passing a challenge examination. These exams are given during the first two weeks of the first semester. Knowledge areas which have not been satisfied at the time of entrance into the M.S. program become conditions on full matriculation. It is the student's responsibility to fulfill his or her conditions at the earliest possible time.

The following table lists courses which satisfy each of the seven knowledge areas.

Programming
- 91.250 Accelerated C with Data Structures, or
- 91.101 Computing I and 91.102 Computing II, or
- 92.267 C Programming and 92.360 Data Structures

Discrete Math
- 91.500 Fundamental Models, or
- 92.321 Discrete Math I and 92.322 Discrete Math II

Calculus
- 92.125 Calculus A and 92.126 Calculus B, or
- 92.131 Calculus I and 92.132 Calculus II

Algorithms
- 91.404 Analysis of Algorithms

Languages
- 91.301 Organization of Programming Languages

Architecture
- 91.305 Computer Architecture Operating Systems
- 91.308 Introduction to Operating Systems

These courses will be offered every Fall, Spring, and Summer semester.

Sc.D. Requirements

Admission to the Doctor of Science degree program requires the demonstration of knowledge of computer science at the Master's degree level, as evidenced by the successful completion of appropriate course work. To be admitted to candidacy, the doctoral student must pass the written departmental qualifying examinations. At a subsequent oral examination, the student, under the direction of a faculty advisor, will propose a thesis topic and demonstrate his/her qualifications to pursue the research. Preparation of the thesis will be directed by a faculty advisor, and the completed thesis will be defended before a committee approved by the department. Representatives of industry and other universities may participate in thesis direction and support.

Financial Support

The Department has a limited number of teaching assistantships available to qualified graduate students. These assistantships can be renewed for up to four years. Other support is available through funded research programs in the departmental laboratories and through cooperative programs with local industry.

MASTER OF SCIENCE DEGREE REQUIREMENTS:

Each degree candidate will be required to pass, with an average of B or better, and not more than two grades below B, the following minimum number of credits, distributed to include one project and one general area:

Core courses
- 91.502 Foundations of CS
- 91.503 Algorithms
- 91.531 Organization of Programming Languages

Project Area
- 6 credits (2 courses with programming assignments from the course pairs list below)

General Area
- 6 credits (2 courses, not necessarily project-related, from the course pairs list below)

Electives
- 3 elective courses

Total: 30 credits

An optional master's thesis can be substituted for at most six credits, and can be used to substitute for one pair of related courses.

DOCTOR OF SCIENCE DEGREE COURSEWORK REQUIREMENTS

The course requirements for the Sc.D. are:

Major Area

• 6 credits (two courses from the course pairs list below)

Minor Area I

• 6 credits (two courses from the course pairs list below)

Minor Area II

• 6 credits (two courses from the course pairs list below)

Sc.D. Thesis

• 24 credits

Total: 42 credits

The major and minor area course requirements for the Sc.D. degree are above and beyond the corresponding requirements for the M.S. degree, but may continue and deepen specializations begun at that level.

The other requirements for the Sc.D. degree include:

• The completion of a written departmental qualifying exam covering the material of the Master's degree core courses and of appropriate material from an additional computer science area selected by the student and his or her advisor.

• The submission and defense at an oral examination of a thesis proposal

• The final defense of the completed thesis through another oral examination.

Students are required to report completion of each of these milestones according to the department's Sc.D. policies. These policies can be found on the department's curriculum Web page: www.cs.uml.edu/curriculum/Grad.html.

M.S./Sc.D. Course Pairs

The following is the list of approved course pairs for both the M.S. and the Sc.D.:

91.563 Data Communications I
91.564 Data Communications II

91.563 Data Communications I
91.555 Computer Networks

91.515 Operating Systems I
91.516 Operating Systems II

91.546 Graphics I
91.547 Graphics II

91.546 Graphics I
91.541 Scientific Data Visualization

91.527 Human-Computer Interaction
91.568 Human-Computer Interaction Seminar

91.527 Human-Computer Interaction
65.790 SWD in Context
91.527 Human-Computer Interaction
91.565 Evaluation of Human-Computer Interaction

91.522 Object-Oriented Analysis and Design
91.523 Software Engineering I

91.523 Software Engineering I
91.524 Software Engineering II

91.523 Software Engineering I
91.521 A Discipline for Software Engineering

91.523 Software Engineering I
91.526 Project Management

91.573 Database I
91.574 Database II

91.551 Computer Architecture
91.553 Parallel Processing

91.504 Algorithms II
91.553 Parallel Processing

91.503 Algorithms I
91.504 Algorithms II

91.531 Programming Language Design
91.538 Semantics of Programming Languages

91.531 Programming Language Design
91.539 Computational Logic

91.538 Semantics of Programming Languages
91.539 Computational Logic

91.543 Artificial Intelligence
91.538 Semantics of Programming Languages

91.543 Artificial Intelligence
91.539 Computational Logic

At most one core course may be "piggybacked" on a project- or general-area course to form a pair of related courses.

COMPUTER SCIENCE DOCTORAL PROGRAM: COMPUTATIONAL MATHEMATICS OPTION

Requirements: (beyond a master's degree)

A. 18 Course Credits (6 courses)

91.515 Operating Systems
91.551 Computer Architecture

four courses in advanced major/minor area electives chosen, under the direction of an advisor, from an approved list of courses

B. 24 Dissertation Credits

Supervised by faculty from the Mathematics and Computer Science Departments

C. Four Qualifying Exams

Computer Science:

1. Programming Languages - based on 91.502 and 91.531.
2. Algorithms - based on 91.503

Mathematical Sciences

Two exams appropriate to the mathematical emphasis chosen. Examples are:

1.Real Analysis - based on 92.501 and 92.502

2.One of

a) Probability and Mathematical Statistics based on 92.587, 92.588 and 92.591.

b) Optimization and Applied Probability based on 92.587, 92.572 and 92.585.

c)Differential Equations and Approximation.

d) Combinatorics and Number Theory.

Any student interested in this program should contact the Chair of the CS Department and/or the Chair of the Mathematics Department.

COMPUTER SCIENCE GRADUATE CERTIFICATE REQUIRMENTS

Certificate in Telecommunications

B.S. in Computer Science/Engineering/Mathematics

91.563 Data Communications I
91.555 Computer Networks
16.543 Introduction to Communication Theory
Approved Elective

Certificate in Human-Computer Interaction

B.S. Degree
91.527 Human-Computer Interaction
91.565 Evaluation of Human-Computer Interaction
65.790 Software Design in Context
Approved Elective

COURSE DESCRIPTIONS

91.500 Fundamentals of Computer Science (3-0)3 Prerequisites: two semesters of Calculus, one semester of Probability and Statistics. Mathematical topics necessary for graduate study in computer science: review of sets, relations, functions; elementary combinatorics; summation calculus, recurrences, generating functions; logic; graphs and trees. This is a remedial course which does not carry credit towards a Computer Science degree.

91.502 Foundations of Computer Science (3-0)3 Prerequisites: 91.500 or 92.322, 91.404 or 91.583, and at least one computer programming course or significant programming experience. An advanced introduction to theoretical computer science. This course will cover the fundamentals of automata, formal languages, and computability theory.

91.503 Algorithms (3-0)3 Prerequisites: 91.500, and 91.404 or 91.583. Co-requisite: 91.502. Abstract types, lists, trees, graphs, sets; relevant algorithms and their worst and average case analyses; fast transforms; polynomial, integer, and matrix algorithms; NP-completeness.

91.504 Advanced Algorithms (3-0)3 Topics in computability, complexity, and analysis of algorithms.

91.505 Formal Languages and Automata (3-0)3 Prerequisites: 91.502 and 91.503. Languages, grammars, and recognizers; Chomsky hierarchy; finite state machines and regular languages; PDAs and context-free languages; context-sensitive languages and their recognition; Turing Machines; open and unsolvable problems.

91.506 Theory of Computation (3-0)3 Prerequisites: 91.502 and 91.503. Examination of models of computation: Turing Machines, Markov algorithms, etc. Recursive function theory; selected topics.

91.507 Computational Algebra (3-0)3 Prerequisites: 91.502 and 91.503. Construction of software for algebraic problems: linear systems, eigenvalues; singular value decomposition; examination of currently available systems.

91.508 Parallel Algorithms (3-0)3 Prerequisites: 91.502 and 91.503. Topics in algorithm design and analysis; mapping and modeling; issues in complexity; lower bounds; models of parallel computation.

91.510 Topics in Fundamentals of Computer Science (3-0)3 Topics of mutual interest to the instructor and students(s) Graph and Network Algorithms Prerequisites: 91.503 or permission of instructor. A review of basics followed by a selection of more advanced topics: the graph isomorphism problem and structural complexity; probabilistic graphs and algorithms; parallel graph algorithms. Emphasis will be placed on investigation and experimentation with implementation of algorithms based on material from Knuth and Mathematica, and possibly additional material from other sources (e.g. DIMACS, etc.)

91.512 Programming Real-Time Systems (3-0)3 Prerequisite: Core courses. Software reliability and fault tolerance. Exceptions and exception handling techniques. Real-time programming languages, including ADA and OCCAM2. Concurrent programming and task scheduling. Process synchronization and communication using semaphores, monitors, and message passing. Timing issues, including real-time clocks, programming time-outs, and delays.

91.515 Operating Systems I (3-0)3 Prerequisites: 91.308 or 91.588, and programming ability in C or C++. This course provides insight into multiprocessing operating systems including processor memory, peripheral, and file systems management in batch, timesharing, real time, and distributed systems targeted for various hardware. Particular emphasis will be placed on techniques of virtual memory as well as the problems of concurrency in both centralized and distributed systems. An OS simulation is a required programming project. Some topics to be covered are process synchronization; high-Level mechanisms for concurrency; processor scheduling and system analysis; deadlock; virtual memory; distributed systems; computer security.

91.516 Operating Systems II (3-0)3 Prerequisites: 91.503 and 91.515. The design and implementation of an interactive multiprocessing operating system to run on a bare hardware system. Separate teams manage the major subsystems with in-class design reviews to coordinate system integration. A functioning system is a class requirement.

91.517 Systems Programming (3-0)3 The design and implementation of assemblers, linkers, loaders, editors, and higher level translation software. Various systems software will be integrated under the operating system built in 91.516 to facilitate a complete programming environment.

91.518 Performance Evaluation (3-0)3 Prerequisites: 91.503, 91.515, and permission of the instructor. Creation of mathematical models of various computer systems and networks; application of queuing theory to evaluation, prediction of behavior, and comparison to model performance.

91.519 Distributed Operating Systems (3-0)3 Prerequisites: 91.503 and 91.515. Topics will include: design paradigms for distributed systems: load balancing and work distribution; naming, searching, and protection in distributed systems; reliability and fault tolerance; case studies of existing systems. Project required.

91.520 Topics in Operating Systems (3-0)3 Topics of mutual interest to the instructor and student(s). Distributed Object-Based Computing Prerequisites: C++ programming, 91.515, and Software Engineering. Distributed computing based on object-oriented facilities is an important development in the design of distributed operating systems and applications. Distributed object-based technologies to be covered include OSF's DCE (distributed computing environment), ODMG object database standard, OMG's CORBA (Common Object Request Broker Architecture), and Microsoft OLE. Students will have source code access to implementations of these systems. Both the design and use of these systems will be discussed.

91.521 A Discipline for Software Engineering (3-0)3 Prerequisites: Programming competence, preferably in C or C++; Recommended: knowledge of one spreadsheet and database system, and basic statistical methods. Practical experience with personal software process management methods, based on Humphrey's text of that name. Basic statistical methods, estimating and measurement techniques for program size, resource usage, schedules and errors.

91.522 Object-Oriented Analysis and Design (3-0)3 Prerequisites: 91.303 and 91.304 and significant C-language programming experience. Object-oriented techniques for analysis, specification, and design. Static information models and state-based dynamic behavior models applied to rapid prototyping projects that both use and implement object-oriented CASE tools.

91.523 Software Engineering I (3-0)3 Prerequisites: 91.522 and 91.502 and (301 or 531). Continuation of 91.522; a team-based project course that applies object-oriented methods to designing, implementing, and maintaining interactive and distributed software systems with emphasis on quality and reusability. (Undergraduates may substitute this course for 91.412.)

91.524 Software Engineering II: Validation and Verification (3-0)3 Prerequisites: 91.503 and 91.523 and familiarity with formal methods. Comparative analysis of program development support systems; specification and code generation techniques for testing and rapid prototyping of large software systems. Introduction to formal specifications and proof-of-correctness. Students will contribute to ongoing software tool development projects.

91.526 Project Management (3-0)3 Prerequisites: Undergraduate Computer Science background or CMS 63.408 or 63.490. Exposure to desktop microcomputers. Programming experience is helpful but not required. Integration of management and software-engineering concepts within a project management context; topics include general management techniques, models and metrics, case studies, and a significant class project.

91.527 Human-Computer Interaction (3-0)3 Prerequisites: Programming ability in C. An examination of the factors that contribute to well-engineered user interfaces for a wide variety of programs. Consideration of

screen design, programming technique, and input devices. Review of human factors literature and development of skills for designing and evaluating user interfaces.

91.530 Topics in Software Engineering (3-0)3 Prerequisites: Permission of the instructor. Topics of mutual interest to the instructor and student(s).

91.531 Programming Language Design (3-0)3 Prerequisites: 91.301 or 91.406, and 91.502. A one-semester course designed to provide students with hands-on understanding of the underlying concepts of programming languages, the principles of their design, and the fundamental methods for their implementation. An executable metalanguage such as Scheme or SML is used throughout the course, facilitating the design of high-level, concise interpreters that are easy to comprehend. The approach is analytical because the salient features of the imperative, functional, object-oriented, and logic programming paradigms are described in the executable metalanguage.

91.534 Compiler Construction I (3-0)3 Prerequisites: 91.301 and 91.503. This course implements a compiler for a complete language. Topics include grammars, syntax, elements of parsing and recursive descent, semantics, basic code generation, fast compilation runtime support. Programming project required.

91.535 Compiler Construction II (3-0)3 Prerequisite: 91.534. Emphasis upon design and implementation techniques and issues for code generation and optimization. The treatment of optimization is pragmatic. Data structures and general principles are emphasized. Formal treatment of languages and grammars continues with the use of compiler construction tools such as flex, bison, yacc, etc.

91.538 Semantics of Programming Languages (3-0)3 Prerequisite: 91.301, and 91.502 or 91.304. Consistent and complementary definitions of programming languages. Axiomatic, operational, denotational, translational, and other semantic approaches. Formal program specification. Verification using the techniques of Floyd and Hoare.

91.539 Computational Logic (3-0)3 Prerequisites: 91.301, and 91.502 or 91.304. Semidecision procedures for first-order logic and their correctness. Tableaus, unification, and resolution. Horn clauses and logic programming. Selected topics in areas such as nonstandard logics and architectures.

91.540 Topics in Languages and Compilation (3-0)3 Prerequisites: 91.301 and permission of the instructor. Topics of mutual interest to students and instructor.

91.541 Scientific Visualization (3-0)3 Prerequisite: 91.546 or 91.427. Topics from the current literature. This course looks at classical and novel methodologies for the visualization of large amounts of data. Examples from the medical literature and from other areas of application will be studied in substantial detail.

91.542 Vision and Imaging Systems (3-0)3 Prerequisite: 91.503. Fundamentals of vision. Mathematical techniques for signal processing; continuous and discrete images; binary images; segmentation; edges and edge finding; reflectance map; optical flow; photogrammetry; pattern classification; polyhedral objects; extended Gaussian images. A project will be required.

91.543 Artificial Intelligence (3-0)3 Prerequisites: 91.301, and 91.503 or 91.304. Search and games, knowledge representation paradigms, natural language understanding, planning, perception. Use of the LISP language for one or more programming projects.

91.544 Multimedia Information Systems (3-0)3 Prerequisites: Background in operating systems and network architectures. Common issues such as synchronization, quality of service guarantees, and dynamic resource management are used to motivate discussion of systems architecture and resource manager algorithms. Basic properties of audio, image, and video media are introduced, and example applications are reviewed. A comprehensive survey of recent research and standardization activities in multimedia systems is made, using an organizational framework introduced in the course.

91.545 Knowledge Based Systems (3-0)3 Prerequisite: 91.543. Topics covered: heuristic searching techniques, languages for symbolic computing (LISP and Prolog), rule-based programming (forward and backward chaining, conflict resolution), production systems (CLIPS and OPS5), frames (hierarchies, attributes, rule integration), blackboard systems, uncertainty (Bayesian updating, Dempster-Shafer theory, and Fuzzy sets and Fuzzy logic), explanation facilities, practical techniques for expert systems development (design and implementation), maintenance of rule-based systems, knowledge based systems in real-time applications and validation, verification, testing, and reliability of expert systems.

91.546 Computer Graphics I (3-0)3 Prerequisites: 91.401 and permission of instructor. Introduction to the hardware, software and mathematics of 2- and 3-dimensional interactive computer graphics systems, including standards, modeling, transformations, hidden-surface removal, shading, and realism.

91.547 Computer Graphics II (3-0)3 Prerequisite: 91.546. Lighting models, photorealism, animation, constructive solid geometry, and distributed graphics.

91.548 Robotics I (3-0)3 Prerequisite: 91.503 and 91.515. Theory of robotics control, manipulation, and vision; current industrial techniques and applications; vision and sensors; factory of the future, and productivity.

91.549 Robotics II (3-0)3Prerequisite: 91.548. Intelligent manufacturing, expert systems for CAD/CAM, autonomous robots, computer integrated manufacturing, robotic planning, and topics in advanced sensors.

91.550 Topics in Graphics, Robotics, and Artificial Intelligence (3-0)3 Topics of mutual interest to the instructor and student(s). Intelligent Industrial Systems. This course is designed to provide the engineer, scientist, or mathematician with an understanding of such software systems and how they are used to build real-time, intelligent solutions. This will be accomplished through case studies of existing systems, reading and presentation of papers, and a project applying various AI techniques (rule-based systems, neural nets, bayesian belief nets, etc.) to a specific industrial problem. G2 will be used as the language for the course; however, either G2 or CLIPS can be used for the project.

Virtual Reality. Prerequisites: Computer Graphics I or the equivalent. Beginning with a systems overview of the requirements for 3DHIAs--human factors, user interface, hardware, software (algorithms and tools), computation and communication--the course continues with a discussion of the issues and the current state of available tools in a historical context. Briefly discussed are the fundamentals of perception in the human visual and auditory system, data representation, and highly interactive virtual exploration spaces. This course will use two virtual environment software packages: Rend386(and VR/Rend386), which run on PC platforms, and VEOS, which runs on Unix workstation platforms. Many algorithms and supporting C and C++ code will be developed, and in some cases, provided by the instructor.

Genetic Algorithms and Neural Networks. Prerequisites: 91.502, 91.503, and some linear algebra and mathematical analysis. This course will introduce the fundamental ideas in genetic algorithms and evolutionary programming, along with ideas and techniques from the field of neural networks. A major consideration will be the interplay between the two conceptual domains.

91.551 Computer Architecture (3-0)3 Prerequisites: 91.305 or 585 and 91.503. An advanced study of computer system organization. Topics include data-path design, control, ALU's, memory organization, distributed processing, theories of parallel computing, advanced architectures, computer communication.

91.553 Parallel Processing (3-0)3 Prerequisites: 91.305 and 91.308. A survey of parallel computer architectures, parallel programming languages, and parallel algorithms, with emphasis on solving practical problems with parallel computers. A final project, typically a substantial parallel program, is required. Usually offered during the Spring semester.

91.555 Computer Networks (3-0)3 Prerequisite: 91.563 and some knowledge of linear algebra and queuing theory.

The two main topics are routing and transport functions, and ATM networks. Routing and transport layer functions in conventional data networks will be examined, with a heavy emphasis on the TCP/IP protocol suite. The ATM is seen as a promising technology for integrated voice/data/video services. The concept of the ATM network will be reviewed. Traffic management functions in ATM networks will explored in detail, including analytic representation of traffic bandwidth and congestion control techniques.

91.560 Topics in Architecture (3-0)3 Topics of mutual interest to the instructor and student(s)

91.563 Data Communications I (3-0)3 Prerequisites: 91.503 and a Calculus-based course in Probability and Statistics. Resource sharing; computer traffic characterizations; multiplexing; network structure; packet switching and other switching techniques; design and optimization; protocols; routing and flow control; simulation and measurement; communications processors.

91.564 Data Communications II (3-0)3 Prerequisite: 91.563 or permission of the instructor. Continuation of 91.563.

91.570 Topics in Data Communications (3-0)3 Topics of mutual interest to the instructor and student(s)

91.573 Database I (3-0)3 Prerequisites: 91.503 and 91.515. Study of various database models including hierarchical, network, relational, entity-relationship, and object-oriented models. This course also covers data design, integrity, security, concurrency, recovery, query processing, and distribution.

91.574 Database II (3-0)3 Prerequisite: 91.573. Continuation of Data Base I. Various issues in the implementation of database systems will be covered.

91.580 Topics in Database Systems (3-0)3 Topics of mutual interest to the instructor and student(s)

91.589 Creating a High-Tech Software Venture (3-0)3 Methodologies for technology forecasting, market research, and discussion of sales channels; forming the team and choosing the CEO; determining the feasibility of the product, developing the technology, and choosing the correct software environment and management tools to market on time and on budget; writing a realistic business plan and evaluating the product's likelihood for success against the plan.

91.590 Topics in Computing Theory (3-0)3 Topics of mutual interest to the instructor and student(s)

91.591 Project (3-0)3

91.592 Directed Study (3-0)3

00-601 Continued Matriculation (3-0)3

91.701 Directed Research (3-0)3

91.702 Directed Research (6-0)6

91.703 Directed Research (9-0)9

91.704 Directed Research (12-0)12

91.740 Masters Project (3-0)3

91.743 Masters Thesis Research (3-0)3

91.746 Masters Thesis Research (6-0)6

91.753 Doctoral Thesis Research (3-0)3

91.756 Doctoral Thesis Research (6-0)6

91.759 Doctoral Thesis Research (9-0)9

DEPARTMENT OF CRIMINAL JUSTICE

Department Chair
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Adjunct Faculty
Ronald P. Corbett, Jr.
(Deputy Commissioner of Probation) A.B. Harvard University; M.S., Northeastern University; Ed.D., University of Massachusetts Amherst.

MASTER OF ARTS IN CRIMINAL JUSTICE

Program Objectives

The Master of Arts in Criminal Justice and the two 12-credit certificates (Domestic Violence Prevention; Leadership and Policy Development) are designed to meet the diverse needs of criminal justice professionals. Courses are offered in three major subject areas: (1) technology and research in criminal justice, (2) criminal justice management and planning, and (3) crime and the community. The program has been designed to accomplish a number of important objectives:

1. To meet the needs of the Commonwealth of Massachusetts for criminal justice graduates to fill positions in teaching, research, and management in criminal justice and related agencies.
2. To prepare students for leadership positions in the administration of criminal justice agencies at the local, state and federal levels as well as in the private sector.
3. To assist students in applying theory and research to real-world problems in criminal justice.
4. To prepare students to conduct quality research on crime measurement, causation, impact, and the effect of state and local policies on crime.
5. To provide students with knowledge about methods of crime control in public and private settings.
6. To provide students with a thorough knowledge of the development of current issues in criminal justice and the relationship of criminal justice to other social and behavioral sciences.
7. To train students in the application of computer technology to decision-making in the criminal justice system.
8. To prepare students to apply skills in research, technology, management and intervention to the unique needs of their communities.

Expected Academic/ Professional/Occupational Results

It is anticipated that the Master's and certificate programs will serve four types of students:

1. Those seeking a terminal master's degree as a prerequisite for entry into the criminal justice field.
2. Those currently in service in the criminal justice system who seek to broaden their skills and obtain job-related knowledge and expertise.
3. Those currently in the criminal justice system seeking to specialize and/or work in some other area of the system.
4. Those currently in the system or pre-service who wish to obtain the training and expertise necessary to meet the growing need for teaching criminal justice at the community college level.

In addition, the program will meet the needs of students preparing for doctoral work in criminal justice or related fields.

A Boston satellite program is available at the McCormack Center.

Admission Requirements

In addition to the requirements for admission listed on page 15 of this catalogue, applicants should have the ability to pursue graduate education, as demonstrated by:

1. Graduation from an accredited four-year institution.
2. Minimum undergraduate grade point average of 2.8 or higher.
3. Acceptable scores on the Graduate Record Examination Aptitude Test, the GMAT or Millers Analogy.
4. Three letters of reference from individuals familiar with the educational and/or professional performance of the applicant.
5. Two copies of a complete and official transcript from each undergraduate and graduate institution attended.
6. An interview may be requested by the Graduate Admissions Committee.

Students with a Bachelor's degree from an accredited program who have an undergraduate grade point average between 2.5 and 2.8 may, with the permission of the Graduate Coordinator, take limited courses as non-degree students. These non-degree students should take 44-501 Foundations of Criminal Justice Scholarship and 44-503 Administration of Justice or other courses with approval. If they successfully complete these two courses with a grade of B or better, they may then make formal application to the program, submitting all required credentials. The Graduate Committee of the Criminal Justice Department then will review all relevant information and make a decision regarding admisssion to the program.

Non-degree status: When space permits, qualified students will be allowed to enroll in selected courses. Subsequent application to the program will permit transfer into the program of no more than twelve credits of course work with grades of B or better.

Degree Requirements

All students will complete a minimum of 33 credits for the Master of Arts degree. Included in the 33 credit requirement is a core course sequence of 15 credits. The core consists of:

44-501 Foundations of Criminal Justice Scholarship 3 cr.
44-503 Administration of Justice 3 cr.
44-521 Criminological Theory 3 cr.
44-580 Quantitative Analysis in Criminal Justice 3 cr.
44-590 Research Methods in Criminal Justice 3 cr.

In addition, all students may complete:

44-743/746 Master's Thesis 6 cr.

B.S./M.A. OPTION

Outstanding undergraduate Criminal Justice majors at the University of Massachusetts Lowell may enroll in a B.S./M.A. program that allows students to complete both degrees in five years. Contact the Graduate Coordinator for additional information.

Degree Program

During the first year of full-time study, students emphasize the five core courses. The decision to complete a thesis should be made before the completion of 24 credits. Full time students will enroll in thesis during the second year of study. Selected specialty courses will be taken during the second or subsequent year.

With the approval of the academic advisor, students may select up to nine credits of graduate level courses in other programs at the university.

Students will be assigned an academic advisor, usually the Graduate Coordinator, when entering the program. Students will be required to maintain a 3.0 cumulative average. If a student should receive a grade of BC or C, the academic advisor will meet with the student to discuss methods of improving performance. No more than six credits of C or BC may be counted toward the degree. If a student should receive a second C or BC, there will be a review by the Graduate Committee for such actions as a warning, probation, or loss of degree candidacy. Such action will be subject to the approval of the Graduate Dean. All requirements for the degree must be completed within five years of the time the

student was first admitted as a matriculated student.

Master's Thesis

The thesis will be completed under the direction of a mutually acceptable thesis advisor. The thesis proposal must be approved by the thesis committee. An approved copy of the proposal will be filed with the Graduate Coordinator. The thesis will represent the student's ability to formulate, carry out, and present a significant research project. A "defense of thesis" will be conducted before a panel including the thesis advisor (chair), and the committee members chosen by the student and approved by the Graduate Coordinator. Thesis forms and guidelines are available.

Course of Study

Once the majority of the required core courses are completed, students are free to choose the remaining courses in their program of study. Courses are clustered into three concentrations: (1) technology and research, (2) management and planning, and (3) crime and the community. Students should meet with their advisor to develop an individualized course of study that best meets their interests and needs.

GRADUATE CERTIFICATES

Graduate Certificate in Domestic Violence Prevention

Domestic violence is one of the major social and public health problems facing residents of the Commonwealth. The existing degree programs in Criminal Justice, Community Social Psychology, and programs in the College of Health Professions each offer relevant courses which facilitate their graduates working with agencies and clients affected by domestic violence. This certificate will bring together these courses, and provide a focused training for those working in settings where domestic violence is an issue.

Required Course:

44/47:622 Family Violence

Plus one of the following:

44:522 Victimology
47:504 The Family System
47:511 Helping Skills I
44:503 Administration of Justice
36:625 Health Policy

Plus:

44:590 Research Methods

Plus one approved elective

These courses may be applied to the master's degree.

Graduate Certificate in Leadership & Policy Development

This graduate certificate provides a focused training for criminal justice managers and administrators. The specialized training received here will increase the knowledge and skills necessary to administer the delivery of high quality and cost effective services. The Certificate Program is designed to respond to the changes taking place in the criminal justice field which now require up-to-date management skills.

Required Courses:

44:570 Criminal Justice Management & Planning
44:573 Public Policy and the Criminal Justice System

Plus two of the following:

44.511 Planning and Program Development
44.531 Law of Administrative Procedures
44.550 Issues in Correctional Administration
44.590 Research methods on Criminal Justice
44.681 Special Topics in Management and Planning

COURSE DESCRIPTIONS

AREA 1: TECHNOLOGY AND RESEARCH

***44.501 Foundation of Criminal Justice Scholarship** (3-0)3 This course is designed to improve the technical writing skills of criminal justice graduate students. Emphasis will be on the fundamentals of written (and oral) report preparation.

44.530 Technology and the Law (3-0)3 The response of the legal system to technological changes in science, engineering and medicine as they affect both the law and the criminal justice professional.

***44.590 Research Methods in Criminal Justice** (3-0)3 Students are introduced to the essential elements of criminal justice research, including criminal justice data sources, conceptualization and measurement, the use of experimental and quasi-experimental designs, survey research, document studies, and ethnographies. The use of computers as a research tool will be covered.

44.591 Research Methods in Criminal Justice II (3-0)3 Specific practice in the definition, design and execution of a research project and an analysis of the impact of contemporary criminal justice research on policy development. Computer applications will be examined.

***44.580 Quantitative Analysis in Criminal Justice** (3-0)3 Students are introduced to a variety of statistical techniques applicable to problem solving in the criminal justice system. This course is designed for both producers and consumers of criminal justice research.

44.592 Criminal Justice Information Systems (3-0)3 A comprehensive examination of the development, utilization and evaluation of computer-based information systems in criminal justice agencies. Focus on the development of management information systems.

44.593 Computer Crime and Security (3-0)3 Examination of the causes and consequences of computer crime, as well as the criminal justice system's response to the problem.

44.594 Crime Analysis and Mapping (3-0)3 Use of new technologies to analyze crime patterns and prevention strategies.

44.680 Special Topics in Technology and Research (3-0)3 Possible topics will include models of decision making, social indicators, comparative research in criminal justice, prediction methods, and advanced statistics for criminal justice.

44.690 Advanced Quantitative Analysis (3-0)3 The application of advanced statistical techniques to research problems in criminal justice. A variety of multivariate statistical techniques will be examined, including OLS regression, discriminant analysis, and LOGIT and PROBIT models.

44.691 Directed Study in Criminal Justice (3-0)3 This course is designed as an independent study of a subject not offered in the standard curriculum.

44.692 Computer Applications in Criminal Justice (3-0)3 Application of computer technology to decision-making in the criminal justice system. A variety of computer applications are presented including computer mapping, forecasting techniques, simulations and modeling.

44.743 Master's Thesis (3,6-0)3
44.746 Master's Thesis (3,6-0)6

AREA II: CRIMINAL JUSTICE MANAGEMENT AND PLANNING

***44.503 Adminstration of Justice** (3-0)3 An examination of the administration of federal, state and local criminal justice agencies in the United States, including the key concepts in criminal law and procedure.

44.511 Planning and Program Development (3-0)3 Examination of the techniques of planning and program develop-

ment in criminal justice agencies. Introduction to the key steps in the planning process, and the program design.

44.531 Law of Administrative Procedures (3-0)3 General principles of administrative law, labor law, application of principles, law enforcement policy making, and implementation of constitutional safeguards. Examination of police unions and political activity.

44.550 Issues in Correctional Administration (3-0)3 Specific analysis of the management of correctional institutions, including custody, classification, reception, programming, release, staffing, scheduling, collective bargaining, prisoners' rights, and other related issues.

44.570 Criminal Justice Management and Planning (3-0)3 A range of criminal justice management issues are addressed, including organizational structure, purpose, rewards and relationships, leadership and management styles, and the development of effective change strategies by criminal justice agencies. The complex role of the criminal justice manager in both the adult and juvenile justice system is emphasized.

44.572 Personnel Administration (3-0)3 Explores current controversies in areas of significant change in personnel administration of criminal justice agencies. Includes collective bargaining, professionalism, motivation, training, productivity, and accountability.

44.573 Public Policy and the Criminal Justice System (3-0)3 Analysis of the interrelationship of criminal justice system components and the political setting surrounding the formulation and administration of public policies for crime control.

44.681 Special Topics in Management and Planning (3-0)3 Courses may include decision theory, budgeting, new managerial perspectives, affirmative action, crime scene management and issues in court administration.

AREA III: CRIME AND THE COMMUNITY

44.520 Crime and the Community (3-0)3 Examines the factors that affect both personal and property crime in different communities. A variety of community-oriented police, court and correctional crime control strategies will be critically analyzed.

***44.521 Criminological Theory** (3-0)3 A detailed examination of the best known and most influential theories of crime causation. Topics include: (1) theory construction, (2) hypothesis testing, (3) theory integration, and (4) the links among theory, research and policy.

44.522 Victimology (3-0)3 An examination of the characteristics and life styles of crime victims and the impact of their victimization. The treatment of victims by the criminal justice system will be examined along with possible reforms in these approaches.

44.533 Elite Deviance and White Collar Crime (3-0)3 Examines the systematic violation of the laws and ethics of business and politics. The structure of power and privilege in relation to both political and economic deviance.

44.541 Community Based Policing (3-0)3 Community policing philosophy, applications, issues, and contemporary research.

44:560 Gender, Race and Crime (3-0)3 The implications of criminal laws, criminal justice practices and programs. Focus on inequalities based on gender, race and class.

44.561 Minorities and the Criminal Justice System (3-0)3 Both social and legal consequences of racism and discrimination will be discussed as they pertain to minorities and the criminal justice system.

44.621 Crime and Crime Prevention in Public Places (3-0)3 Examination of current theory and research on crimes in schools, libraries, museums, mass transit, parks, and other public places. Crime prevention and security programs appropriate for these public places will be emphaisized.

44.622 Family Violence (3-0)3 The causes and consequences of intra-family violence will be examined. Topics will include child abuse and neglect, sexual abuse, spouse abuse, and abuse of the elderly. Alternative techniques for dealing with these problems will be stressed.

44.623 Child Maltreatment (3-0)3 Introduction to empirical findings and theoretical perspectives concerned with the maltreatment of children and youth. Examination prevalence, risk factors, consequences, and system responses.

44.635 Constitutional Rights in Criminal Procedure (3-0)3 An examination of constitutional rights through the most recent decisions. This includes an analysis of the 1st, 4th, 5th, 6th, 8th, 9th and 14th amendments (i.e., search and seizure, arrests, bail, juries, trials, cruel and unusual punishment, etc.)

44.650 Community-Based Corrections (3-0)3 The history and development of programs relating to community treatment of offenders; the philosophies and programs dealing with the rehabilitation and integration of the offender into society.

44.675 Community Relations for Criminal Justice Professionals (3-0)3 Research underlying the ideal of effective communication and persuasion. The application of communication theory to relevant situations. Preventing and dealing with potential crises.

44.682 Special Topics in Crime and the Community (3-0)3 Topics may include victim compensation, sexual offenders, crisis management, comparative studies of crime and crime prevention, women and crime and intensive supervision in probation and parole.

DEPARTMENT OF MATHEMATICS

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Richard Winslow
Assistant Professor; B.A., Columbia University; M.A., Ph.D., Brandeis University.
Mark Q. Yin
Professor; Ph.D., University of Pittsburgh.

MASTER OF SCIENCE DEGREE PROGRAM

There are four options available in this program:

A. Applied Mathematics
B. Scientific Computing
C. Statistics and Operations Research
D. Mathematics for Teachers

All four options require a four-year undergraduate degree from an accredited college or university with a satisfactory grade point average, and the official score report of the Aptitude Test of the Graduate Record Examination. For options A, B and C the degree must be in mathematics or a related discipline. For option D, three semesters of calculus (12 credits) are required. Applicants lacking some prerequisites may be accepted as matriculated with conditions.

The programs consist of thirty credit hours approved by the Graduate Curriculum Committee. These include both required courses and electives (which may be offered in other departments). Up to six credits at the 400 level may be considered for inclusion in the program of study. In addition three or six credits may, with the permission of the student advisor and Graduate Commitee, be obtained by thesis.

Most courses are offered on a regular basis in the late afternoon and early evening so that all programs can be completed on a part-time basis.

A. Applied Mathematics

The M.S. Option in Applied Mathematics focuses on techniques of mathematical modeling and the basic tools needed to investigate problems from both a theoretical and computational viewpoint. Courses range from classical applied mathematics to state of the art courses in signal processing and wavelets.

Required courses: Applied Mathematics I and II, Numerical Analysis, Numerical Linear Algebra, Real Analysis I, Complex Analysis I.

B. Scientific Computing

The explosive growth in computer use has brought an ever-increasing demand for trained computer professionals. Many individuals have a scientific background which includes programming experience but have little formal education in computational mathematics. The Scientific Computing option is specifical-

ly tailored to the needs of such students.

Required courses: Algorithms, Numerical/ Analysis, Numerical Algebra, Algebraic Structures, Discrete Mathematics.

C. Statistics and Operations Research

This option is a professionally oriented program that provides the necessary mathematical skills to solve many of the data analysis and optimization problems of government, industry, science, engineering, and management.

Required courses: Probability Theory, Mathematical Statistics, and Linear Statistical Modeling and Regression Analysis.

D. Mathematics for Teachers

The Master of Science in Mathematics for Teachers Program aims to give students a balanced combination of theory and practice, to enhance their appreciation and understanding of Mathematics as a science, and to provide them with the tools necessary to instill in their own students an interest in the subject. Courses in Mathematical Analysis, Discrete Mathematics, Linear Algebra, Number Theory, Geometry, and Probability and Statistics are designed to introduce the student to several important areas of Mathematics. Courses in Problem Solving, History of Mathematical Science, Mathematical Modeling, and Computers in the Classroom are intended to provide a deeper awareness of the contexts in which mathematical activity takes place and of the mental processes and technological aids employed by people in solving practical problems. Note that this is not a teaching certification program - contact the College of Education for information about certification.

Required courses: Mathematical Analysis, Problem Solving.

FIVE YEAR B.S./M.S. PROGRAM

The department has a five year B.S./M.S. program for outstanding undergraduates. See the undergraduate catalog for details.

COURSE DESCRIPTIONS

92.500 Discrete Structures (3-0)3 An introduction to discrete mathematics, including combinatorics and graph theory. The necessary background tools in set theory, logic, recursion, relations, and functions are also included.

92.501 Real Analysis I (3-0)3 Real and complex number systems. Sequences and series. Topology of the real line: completeness, compactness, continuity. Differentiability of single variable functions. Sequences and series, including uniform convergence.

92.502 Real Analysis II (3-0)3 Topology of metric spaces, Multivariable functions, derivatives as linear maps, Jacobians, inverse and implicit function theorems, Taylor's theorem, introduction to measure theory.

92.503 Mathematical Analysis (3-0)3 Metric spaces: completeness, compactness, connectedness. Continuity. Discontinuities. Uniform convergence. Power series. Differentiation. Integration. This course is generally applicable only to the Teacher Option.

92.505 Discrete Mathematics (3-0)3 Prerequisite: Linear Algebra or Discrete Structures. Basic counting rules, permutations and combinations, recurrence relations. Asymptotic algorithms analysis, NP-completeness, heuristic algorithms. Linear, integer, and dynamic programming. Coding Theory. Applications.

92.507/508 Applied Functional Analysis I, II (3-0)3, (3-0)3 Vector, metric, normed, Banach and Hilbert spaces. Spectral theory of linear, compact, and unbounded linear operators. Integral and differential equations, approximation theory, and quantum mechanics.

92.509 Introduction to Probability and Mathematical Statistics I (3-0)3 Prerequisite: Calculus III. This course provides a solid basis for further study in statistics, simulation, or pattern recognition and neural networks. It is especially appropriate for students with an undergraduate science or engineering major who have not had a rigorous calculus-based probability and statistics course. Topics include probability models, random variables, distributions, independence, expected value, variance and higher moments, transformation of random variables, moment generating functions, conditional probability densities and the central limit theorem.

92.510 Computers and Calculators in the Classroom (3-0)3 This course will explore the roles of mainframes, PC's and hand calculators in instruction, examine some of the available software and consider their use in a variety of areas of secondary mathematics, such as algebra, geometry (Euclidian and analytic) probability and statistics and introductory calculus. This course is generally applicable only to the Teacher Option.

92.511 Complex Variables I (3-0)3 Complex numbers, elementary functions and their geometric representation. Differentiation and integration. Power series. Singularities. Entire and meromorphic functions. Periodic functions.

92.512 Complex Variables II (3-0)3 Prerequisite: Real Analysis I. Differentiation and integration of complex analytic functions. Cauchy's integral theorem and formula. Singularities and Laurent series. Theory of residues and applications. Harmonic functions. Conformal mapping.

92.513 Number Theory (3-0)3 Study of primes, congruences, number-theoretic functions, Diophantine approximation, quadratic forms and quadratic number fields. Additional topics as time permits.

92.515 Chaos Theory and Dynamical Systems (3-0)3 Prerequisite: Calculus. Orbits, graphical analysis, periodic points, bifurcations, quadratic family, transition to chaos, symbolic dynamics, chaos, Sarkovskii's theorem, Schwarzian derivative, fractals, Julia sets and the Madelbrot set.

92.516 Pattern Recognition (3-0)3 Prerequisite: Calculus, probability, matrix algebra. Random vectors: Transformations of Random Vectors. Hypothesis Testing: Error Probability, Sequential Tests. Supervised Learning. Nearest Neighbor and Parzen Kernel Approach, Feature Extraction.

92.517 Neural Networks (3-0)3 Prerequisites: Calculus based probability and statistics, linear algebra. Projection pursuit and neural networks, back propagation, greedy approximation, NP-completeness of network training, the Hopfield network, structural pattern recognition and combinatorial classification.

92.520 Mathematical Problem Solving (3-0)3 The course will focus on four basic factors that determine effective mathematical problem solving: mathematical resources, ability to use heuristics, ability to control the use of resources and heuristics, and the student's beliefs about the use of mathematics to solve problems and about himself or herself as a problem solver. Effective strategies for incorporating problem solving in the curriculum will also be discussed.This course is generally applicable only to the Teacher Option.

92.521/522 Algebraic Structures I, II (3-0)3, (3-0)3 Properties of rings, groups, fields, polynomials over fields, extension rings and fields, vector spaces, codes, and additional applications.

92.523 Linear Algebra (3-0)3 Sets and maps. Vector spaces and linear maps, the matrix of a linear map, solving systems of equations, scalar products and orthogonality, eigenvalues and applications.

92.527 Geometry (3-0)3 A wide survey of topics related to secondary school geometry: axiomatic systems and Euclidean geometry, constructions in geometry, analytic geometry, introduction to non-Euclidean geometry, and historical development. This course is generally applicable only to the Teacher Option.

92.529 Differential Geometry (3-0)3 Differential geometry involving curves and surfaces in 3-space. Curvature, torsion,Frenet equations, intrinsic equations, involutes and

evolutes.

92.530/531 Applied Mathematics I, II (3-0)3, (3-0)3 Vector calculus, divergence, Green's and Stokes' theorem, series solution of differential equations, boundary value problems, Fourier series and integrals, partial differential equations, separation of variables, special functions.

92.535 History of Mathematical Science (3-0)3 Ancient numeral systems, Babylonian and Egyptian Mathematics, Pythagorean Mathematics, Duplication, Trisection and Quadrature, Euclid's Elements and Greek Mathematics after Euclid, Hindu and Arabian Mathematics, European Mathematics from 500 to 1600, Origins of modern Mathematics, Analytic Geometry, History of Calculus, Transition to the 20th Century, Contemporary Perspectives. This course is generally applicable only to the Teacher Option.

92.537 Vector and Tensor Analysis I (3-0)3 The geometry of curves and surfaces, Serre-Frenet formulas, intrinsic equations of a curve, first and second fundamental forms of a surface, divergence, curl, and gradient.

92.538 Vector and Tensor Analysis II (3-0)3 Tensor algebra, covariant and contravariant differentiation and parallel displacement. Applications to differential geometry and selected topics.

92.539 Differential Forms and Their Applications I (3-0)3 Vector calculus, curves and surfaces, differential forms and multilinear maps.

92.540 Differential Forms and Their Applications II (3-0)3 The gradient, curl, and divergence as exterior derivatives, the general Stokes' Theorem, applications to electrodynamics and thermodynamics.

92.541/542 Fourier Analysis and Boundary Value Problems I,II (3-0)3, (3-0)3 Prerequisite: Real Analysis I. Fourier series and integrals. Orthogonal systems and Sturm-Liouville problems. Applications to boundary value problems in rectangular, cylindrical, and spherical coordinates. Distributions and their applications.

92.543 Ordinary Differential Equations (3-0)3 Prerequisite: Real Analysis I. Existence, uniqueness, and smoothness of solutions. The Poincare-Bendixson theory. The neighborhoods of critical points and closed orbits. Liapunov stability. Linear and perturbed linear systems. Applications.

92.545/546 Partial Differential Equations I,II (3-0)3, (3-0)3 Introduction to partial differential equations in the plane and space, with engineering applications. Solution of initial and boundary value problems. Complex variables and transform theory.

92.547 Integral Equations (3-0)3 Exact, iterative, and numerical solutions of Volterra and Fredholm integral equations, general operators. Symmetric kernels, orthogonal system of functions, and the Hilbert-Schmidt theorem. Applications.

92.548 Mathematics of Signal Processing (3-0)3 Prerequisite: Real Analysis I. Representation of signals: Fourier analysis, fast Fourier transforms, orthogonal expansions. Transformation of signals: linear filters, modulation. Band-limited signals. Sampling. Uncertainty principle. Windows and extrapolation. Applications to medical imaging and array processing.

92.550 Mathematical Modeling (3-0)3 Prerequisite: Calculus, Differential Equations. This course is devoted to studying the application of mathematics to real-life problems from the physical, biological, social, and behavioral sciences. Experience is provided with a wide variety of models.

92.551 Calculus of Variations (3-0)3 Prerequisite: Real Analysis I. The first variational problem: necessary and sufficient conditions for weak and strong extrema. Constraints and Lagrange multipliers. Optimal control.

92.552 Wavelet Analysis (3,0)3 Prerequisite: A working knowledge of Fourier series and integrals, and some familiarity with orthogonal expansions of functions. Consult the instructor. Introduction to time-frequency localization of signals, frames, windowed Fourier transforms, continuous and discrete wavelet transforms, time-frequency sampling theorems, orthonormal bases of wavelets, algebraic wavelet theory, applications to electrodynamics and optics.

92.553 Systems Simulation and Modeling (3-0)3 Prerequisite: Knowledge of a programming language. Procedures in model construction and computerized simulation, modeling tools and techniques, model conceptualization and implementation, selected applications of simulation.

92.560 Data Structures and Algorithms I (3-0)3 Prerequisite: Discrete Structures and Intro to Data Structures. Implementations of lists, stacks, queues, ordered and binary trees, and priority queues. Tree traversals. Open and closed hashing. Directed graphs: shortest paths and acyclicity.

92.562 Perturbation Methods (3-0)3 This course provides an introduction to perturbation methods and asymptotic expansions. Topics include local asymptotic approximations for ordinary differential equations, asymptotic expansion of integrals, and global analysis of ordinary differential equations via boundary layer theory, WKB theory, and multiple-scale analysis.

92.563 Numerical Analysis (3-0)3 Prerequisite: Real Analysis I. Non-linear equations in one and several variables. Numerical differentiation and integration. Numerical methods for ordinary differential equations and for the Laplace, heat, and wave equations.

92.564 Numerical Algebra (3-0)3 Solution of linear systems. Eigenvalue, eigenvector problem. Fast Fourier Transform. Introduction to finite elements. Least squares. Splines, Chebyshev approximation.

92.565 Formal Languages (3-0)3 Principles of finite automata. Properties of languages accepted by finite automata. Context-free grammars and push-down automata. Turing machines and computability.

92.566 Theory of Computation (3-0)3 Prerequisite: Knowledge of a programming language. Computability, undecidability, complexity. Turing machines and the halting problem. Elementary recursion theory. The Church-Turing thesis. Measures of complexity, the speed-up theorem. Proving theorems about programs.

92.570 Probability and Statistics (3-0)3 Overview of descriptive statistics, data analysis, probability of events, discrete random variables, continuous random variables, normal, binomial and other probability distributions, central limit theorem, survey sampling, estimation, hypothesis testing, regression, experimental design, analysis of categorical data, nonparametric statistics. This course is generally applicable only to the Teacher Option.

92.571 Linear Optimization (3-0)3 Simplex and revised simplex methods, duality, sensitivity analysis, the transportation problem and other applications, degeneracy procedures, computational techniques. Introduction to integer programming.

92.572 Non-Linear Optimization (3-0)3 Unconstrained optimization, Lagrange multipliers, Kuhn-Tucker theory, quadratic programming, convex programming, numerical methods.

92.575 Data Structures and Algorithms II (3-0)3 Prerequisite: Data Structures and Algorithms I. Divide and conquer, radix and comparison sorts, order statistics, union-find, balanced trees, graph connectivity, path finding, matrix multiplication, fast Fourier transform, pattern matching, NP-completeness.

92.579 Reliability and Life Data Analysis (3-0)3 Prerequisite: Probability or Statistics for Engineering and Science. Introduces statistical methods for analyzing data obtained from lifetime testing of products. Statistical failure models, testing reliability hypotheses and accelerated life testing.

92.580 Combinatorics (3-0)3 Prerequisite: Calculus and Discrete Mathematics Generating functions, recurrence relations, inclusion-exclusion, Polya theory. Experimental designs (block design). Partially ordered sets. Applications.

92.581 Graph Theory (3-0)3 Prerequisite: Linear Algebra or Discrete Structures. Terminology, theorems, algorithms, and applications of graph theory. Trees, circuits, and connectivity. Hamiltonian and Eulerian graphs. Shortest routes, matching, network flows. Covering, coloring, Ramsey theory.

92.582 Time Series Analysis (3-0)3 Prerequisite: Permission of instructor. Building models for discrete time series, and their use in forecasting and control.

Stationary and non-stationary time series models. Box-Jenkins (ARMA) and other techniques.

92.583 Cryptography (3-0)3
Prerequisite: Permission of instructor. Basic concepts, some classical cryptographic examples, modern encryption algorithms, the Data Encryption Standard (DES), public key systems, probabilistic encryption, aspects of key management and inverence controls in statistical data bases.

92.584 Stochastic Processes (3-0)3
Prerequisite: Probability or Mathematical Statistics I. Markov chains and processes, random walks, stationary, independent increments, and Poisson processes. Ergodicity. Examples (e.g., diffusion, queuing theory, etc.).

92.585 Queuing Theory (3-0)3
Prerequisite: Statistics and Probability. Single-server queuing systems, queue length, and waiting time. Multi-server queuing systems. Modeling of telephone systems, interactive computer systems.

92.586 Coding Theory (3-0)3 Prerequisite: Discrete Structures. Error correcting and decoding. Applications to data processing, transmission and security. Linear block, cyclic, convolution and arithmetic codes. Applications from communications and computer science.

92.587/588 Probability Theory and Mathematical Statistics (3-0)3, (3-0)3
Random variables, densities, joint and conditional distributions, expectations, variance, estimation, sufficiency and completeness, hypothesis testing, limiting distributions.

92.589 Theory and Methods of Sampling From Finite Populations (3-0)3 Simple random sampling, systematic sampling, stratified random sampling, multistage cluster sampling, regression estimation, ratio estimation, effect of costs on sample allocation and non-sampling errors.

92.590 Statistical Quality Control (3-0)3
Prerequisite: Probability or Statistics for Engineering and Science. Introduction to statistical methods useful in quality assurance. Theory and application of control charts for variables and attributes. Process capability analysis. Acceptance sampling. Introduction to reliability/survival analysis.

92.591 Linear Statistical Modeling and Regression Analysis (3-0)3 Prerequisite: Probability, Biostatistics, or Statistics for Engineering and Science. Simple linear regression, distributions of estimators, confidence regions, the general linear statistical model, setting up the generalized likelihood ratio test for H: u lies in affine space L when the model is Y = u + E. Applications to multiple linear regression. Testing for homoscedasticity. Initial data transformations. Confidence ellipsoids. Testing hypotheses about regression parameters. Analysis of residuals, residual plots, variance stabilization. Application of the general linear model to polynomial regression and one, two and three factor analysis of variance.

92.592 Multivariate Statistical Modeling (3-0)3 Model building via least squares. Discriminant and factor analysis, principal components, profile analysis, canonical correlation, cluster analysis. Experience on real data sets.

92.593 Experimental Design (3-0)3 Use of designed experiments to gain information faster and more efficiently than using trial-and-error, while controlling extraneous factors. Factorial and fractional factorial designs with each factor at two levels (the heart of modern off-line quality control). Classical analysis of variance models including factorial, blocked and hierarchical (nested) designs. Introduction to interlaboratory testing and response surface methodology. Designing, carrying out, analyzing and reporting results of real experiments.

92.594 Control Theory (3-0)3
Prerequisite: Real Analysis I. Analytical and numerical methods for optimization of deterministic and stochastic dynamic systems.

92.595 Information Theory (3-0)3
Prerequisite: Real Analysis I. Shannon theory including information measure and transmission rates and capacities. Elements of coding theory.

92.596 Finite Element Methods (3-0)3
Prerequisite: Real Analysis I . Mathematical formulations and techniques including an introduction to variational methods. Examples from solid mechanics, heat transfer, and fluid mechanics.

92.597 Introduction to Probability and Mathematical Statistics (3-0)3
Prerequisite: Real Analysis I. Continuous random variables, probability density functions, cumulative distribution functions, expected value and variance of random variables. Functions of random variables. Classical distributions, including normal (Gaussian), gamma, chi-square, t and F. Statistical methods including sampling, hypothesis testing and estimation.

92.599 Approximation Theory (3-0)3
Prerequisite: Real Analysis I. Uniform approximation by polynomials. The Weierstrass and Jackson theorems. Characterization of best approximation. Least squares approximation. Approximation by splines and rational functions.

92.651/652 Directed Studies I,II (3-0)3, (3-0)3 Prerequisite: Permission of instructor. This course is intended to satisfy individual student needs. Topics include various fields of mathematics.

92.653/660 Selected Topics I,II (3-0)3
Prerequisite: Permission of instructor. Advanced topics in various fields of mathematics and related fields. Coverage varies from term to term.

92.743, 746 Master's Thesis 3,6

DEPARTMENT OF MUSIC

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Peter McCoy
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Anthony Mele
Professor, Piano; B.M., Ithica College; M.M. Boston University.
William Moylan
Professor, Sound Recording Technology; B.M., Peabody Conservatory, Johns Hopkins University; M.M., University of Toronto; D.A., Ball State University.
Ingul Ivan Oak
Professor, Voice; B.M., M.M., New England Conservatory.
John Ogasapian
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Kay George Roberts
Professor, Conducting & Strings; B.A., Fisk University; M.M., M.M.A., D.M.A., Yale University.
Rosita M. Sands
Professor, Music Education; B.M.E., M.A., Florida State University; M.Ed., Ed.D., Columbia University.
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W. Anne Trenkamp
Professor, Music Theory; M.M., University of Michigan; B.A., Ph.D., Case-Western Reserve University.

Adjunct Faculty:
Eunice Alberts
Voice; B.M., New England Conservatory.
Judith Bedford
Bassoon; B.M., M.M., New England Conservatory.
Anne Black
Violin; B.A., University of California; M.M., Yale Univesity.
Fred Buda
Percussion; B.M., Boston University.
Sandra Carlson-Wood
Woodwinds; B.S., University of New Hampshire; M.M., University of Massachusetts Lowell.
Jeffrey Dorenfeld
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Janice Giampa
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Mark Henry
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Tad Hitchcock
Guitar.
Keith Jones
Sound Recording Technology; B.A., Hartwick College; M.A., San Francisco State University; M.A., Ph.D, Stanford University.
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Paul Lehrman
Sound Recording Technology; B.F.A., SUNY/Purchase.
Daniel Lutz
Instrumental Ensemble.
William MacMullen
Music Education
Ellen Michaud-Martins
French Horn B.M., University of Lowell; M.M., New England Conservatory.
Martin Polon
Sound Recording Technology; A.B., M.A.,University of California.
Coleman Rogers
Sound Recording Technology; B.M., Brown University.
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David Thibodeau
Sound Recording Technology; B.S., Middle Tennessee State University.
Juanita Tsu
Piano; B.M., Peabody Conservatory; M.M., New England Conservatory.
Susan Turcotte-Gavriel
Music Education; B.M., University of Massachusetts Lowell.
Jonathan Wheatley
Guitar.
Alan Williams
Sound Recording Technology; B.M., New England Conservatory.
Douglas Worthen
Flute; B.M., B.M.E., Hartt School of Music; M.M., New England Conservatory.

Objectives of Graduate Programs in Music

The graduate programs in Music are committed to the continued acquisition of musical knowledge and professional competence and the development of research skills. The specific objectives of the various degree programs are listed under the individual program descriptions.

General Requirements for Admission

Applicants for admission to the Master of Music degree program must possess a bachelor's degree or its equivalent with a major in music. Those holding degrees in other disciplines will be expected to take prerequisite undergraduate courses for no graduate credit to bring their skills to a level commensurate with that attained by an undergraduate music major. Some prerequisites may be waived, at the discretion of the Music Department, through distinguished results on placement examinations and performance auditions.

All applicants are expected to present an undergraduate record of sufficient quality to assure a reasonable expectation of successful graduate achievement. Candidates for admission must submit the required Graduate School application forms and official transcripts of previous post-secondary education.

Each program requires additional materials or examinations which must be completed or filed by the applicant. Please review the materials below for information on individual programs.

Placement Examinations and Advising

Upon arrival, all entering graduate students are required to take placement examinations in Music Theory and Music History. The Music Department office should be consulted for specific test dates.

Successful candidates for admission will be assigned a faculty advisor and notified of registration dates and other pertinent information.

General Program Requirements

All Master of Music programs require a minimum of 30 credits, including 74-596, Introduction to Graduate Study in Music. Each program requires either a thesis, project report, or recital project. Specific requirements are listed under program descriptions.

MASTER OF MUSIC IN PERFORMANCE, APPLIED PERFORMANCE OPTION

Objectives

The Master of Music degree in Performance is designed to create and maintain the highest level of instruction; to offer courses that are both intellectually stimulating and artistically challenging; to develop performance skills and provide students the experience of performing in large and small ensembles as well as solo recitals; to guide the student's course of study by developing programs that focus directly on attaining a level of professional competence which will help ensure success upon completion of the degree.

Admission Requirements

In addition to the admission requirements for all applicants to the Master of Music degree program, applicants to the Master of Music degree in Performance must accomplish the following:

Auditions

Auditions are held on specific published dates during each academic year, and applicants who meet the general admission criteria will be invited to attend the next scheduled audition following processing of the application materials. Applicants who live at too great a distance may submit a tape directly to the Coordinator of Graduate Studies, but will be expected to audition in person at the beginning of their initial semester of matriculation. Vocal performance applicants must demonstrate proficiency in French, German, and Italian diction.

Admission Requirements - Letters of Recommendation

The three required letters of recommendation submitted with the Graduate School application should be from persons in a position to evaluate the musical skill and accomplishment of the applicant.

	Program Requirements	
74-596	Introduction to Graduate Study in Music	3
	Applied Music	16
	Ensemble	8
	Electives in Music (500 Level and above)	6
	Recital*	

*Two public recitals, each accompanied by submission of a written research document, are required. (See department guidelines for information pertaining to preparation of research document).

MASTER OF MUSIC IN PERFORMANCE, CONDUCTING OPTION

Objectives

The Master of Music degree in Performance, conducting option, is designed to create and maintain an environment of instruction, opportunity and artistic endeavor in which students can develop their individual conducting skills to a level of professional competence fully supported by thorough music knowledge, within the context of a program flexible enough to be responsive to the goals and aspirations of each individual student.

Admission Requirements

Auditions

In addition to the admission requirements for all applicants to the Master of Music degree program, applicants to the Master of Music in Performance, conducting option degree program will be auditioned in both conducting and the applicant's major medium of performance. Those who live at too great a distance may submit video and audio tapes, to the Coordinator of Graduate Studies, but will be expected to audition in person at the beginning of the initial semester of matriculation.

Applicants must also present evidence of undergraduate studies in the following areas:

a. conducting,
b. instrumentation and/or orchestration,
c. studies in several areas of music performance representa tive of the families of musical instruments, i.e., strings, wood winds, etc.

Letters of Recommendation

The three required letters of recommendation submitted with the Graduate School application should be from persons in a position to evaluate the musical skills and accomplishments of the applicant, as well as the applicant's potential as a conductor.

Program Requirements

74-596	Introduction to Graduate Study in Music	3
	Applied Music	2.2

	Ensembles	1,1
75-550	Seminar in Instrumental Conducting Techniques	3
75-552	Seminar in Choral Conducting Techniques	3
75-654	Seminar in Instrumental Literature	3
75-656	Seminar in Choral Literature	3
75-650	Conducting Practicum & Seminar I*	3
75-652	Conducting Practicum & Seminar II*	3
Music Electives		6

*Conducting proficiency must be demonstrated while the student is enrolled in the Practica courses. Conducting Practicum & Seminar II involves a public conducting performance and the presentation of a related analytical document, which are judged by a panel of assigned faculty. Conducting Practicum & Seminar II is usually completed during the final semester of residence, and is a terminal requirement for the degree.

MASTER OF MUSIC IN MUSIC EDUCATION

Objectives

The Master of Music, Music Education degree program provides advanced study of music teaching and learning and professional preparation for those engaged in or aspiring to a career as a music teacher. The degree program consists of two options: a research-based thesis option for fully-certified music teachers and a teacher certification option for newly-certified music teachers who are in the process of earning their standard certification.

The degree program is designed to facilitate students' growth and development as leaders in the profession of music education; as creative problem solvers and innovative thinkers; as individuals who love music and the arts and utilize their knowledge of and enthusiasm for music to inspire students; and as contributors, through research, to the profession and discipline of music education.

The Music Education curriculum is based on the belief that music educators must have comprehensive knowledge of the subject matter of music, an awareness of current theory and practice in music education, and an understanding of recent curriculum developments and contemporary issues in general education.

Admission Requirements

In addition to the admission requirements for all applicants to the Master of Music programs, applicants to the music education program must submit:

1. An official score for the Miller Analogies Test or Graduate Record Examination (verbal and analytical parts only). Scores must be mailed directly to the Graduate School;
2. resume;
3. Three letters of recommendation from persons qualified to evaluate academic, musical, and professional capabilities. Forms for these recommendations are available in the Graduate School application materials.
4. For the thesis option: a. verification of standard certification in music and /or proof of music teaching experience; b. a sample of your scholarly writing about music or music education. This may be a term paper or research paper written in any baccalaureate level music class, providing evidence of writing skills and potential for writing at the level of a graduate thesis.
5. For the certification option: a. verification of provisional certification and proof of music teaching experience or provisional certification, with advanced standing. b. an essay of at least three typewritten pages addressing the following:

-the applicant's purpose and specific objectives in pursuing graduate study in music education;

-the applicant's philosophy of education in general and arts education in particular;

Comprehensive Examination

Music education candidates must pass a comprehensive examination in music education, and all candidates may expect to be examined in depth in their major area of concentration. Further information as to the nature and scope of the comprehensive examinations may be obtained from the advisor or department chair.

Program Requirements

1. Research/Thesis option

74-596	Introduction to Graduate Study in Music	3
71. 74.	Music History or Theory requirement	3
7	Music electives	3
7	Applied lessons	2,2
7	Ensembles	1,1
73.601	Seminar in Music Education	3
73-551	Research in Music Education	3
73.	Music education electives	6
73.743	Thesis	3
		TOTAL:30

2. Certification option

74.596	Introduction to Graduate Study in Music	3
71. or 74.	Music History or Theory requirement	3
7	Music electives	6
73.591	Multicultural Music Education	3
73.601	Seminar in Music Education	3
73.551	Research in Music Education	3
73.	Music education electives	4
73.695	Clinical Experience	3
73.696	Project Report	2
		TOTAL:30

COURSE DESCRIPTIONS

Music Theory & History/ Literature

71.500 Theory Review (3-0)3
A review of common-practice part writing and analysis. Credit cannot be applied toward the Master of Music degree requirements.

71.501 Analytical Techniques (3-0)3
Formal, contrapuntal and harmonic analysis of common practice repertoire.

71.503 Theoretical Concepts (3-0)3
A study of major concepts in music theory from Rameau to the present.

71.526 Analysis of Contemporary Music (3-0)3
Formal, contrapuntal and harmonic analysis of twentieth century repertoire, both serial and non-serial.

71.601 Topics in Common Practice Analysis (3-0)3 Pre-requisite: 71.501. Exploration of individual topics in theory and compositional technique linked to an area of historical interest to the student.

71.626 Topics in Contemporary Musical Analysis (3-0)3 Pre-requisite: 71.526 or permission of instructor. Exploration of individual topics in theory and compositional technique linked to a twentieth-century area of special interest.

71.743 Thesis (3-0)3 Course Offerings in Music History and Literature.

74.539 Eighteenth and Nineteenth Century American Music (3-0)3
Examination of various aspects of American art music during its formative decades.

74.548 J.S. Bach (3-0)3
Representative music of the composer. Emphasis on the stylistic traits and latest

research reordering the chronology of Bach's work.

74.549 Mozart (3-0)3
An in-depth study of the development of Mozart's compositional style through an examination of representative works.

74.564 History of Music Theory (3-0)3
A survey of the main currents of musical notation, theory and philosophy from the classical and patristic philosophers to the present.

74.567 Musicology and Research I (3-0)3

74.568 Musicology and Research II (3-0)3

74.596 Introduction to Graduate Study in Music (3-0)3
Research techniques, bibliography, form and style in the preparation of formal scholarly papers in music.

74.597 Topics in Musicology I (3-0)3

74.598 Topics in Musicology II (3-0)3

74.661 Seminar in Medieval Music (3-0)3

74.662 Seminar in Renaissance Music (3-0)3

74.663 Seminar in Baroque Music (3-0)3

74.664 Seminar in Music of the Classic Period (3-0)3

74.665 Seminar in Romantic Music (3-0)3

74.666 Seminar in Twentieth Century Music (3-0)3

74.667 Seminar in Musicology (3-0)3

74.668 Seminar in Musicology (3-0)3

COURSE DESCRIPTIONS

Course Offerings in Music Education*

*Subject to program modifications.

73.55l Research in Music Education (3-0)3 Methods of scientific inquiry, research methodologies, and current research in music education; study of the research process including gathering, evaluating, and reporting of data; examination of information resources, research publications, and scholarly writings in the discipline.

73.570 Seminar in Administration and Supervision of Music Education (3-0)3
Lectures, readings, discussion, and individual research projects on topics relevant to administration and supervision in music education, K-12.

73.60l Seminar in Music Education (3-0)3 Lectures, readings, discussion, and individual research projects focusing on a range of topics in contemporary music education including: philosophy in music education, current issues in music education; and national and state curricular developments.

73.695 Clinical Experience (3-0)3
Post-baccalaureate music teaching experience in K-12 schools under the supervision of music specialists, administrators, and members of the college faculty; Provides setting for the application of principles studied in graduate music and music education coursework and the integration of theory and practice.

73.696 Project Report (2-0)2 A scholarly research project with a pedagogical focus, resulting in a comprehensive written document.

73.743 Thesis in Music Education (3-0)3

73.565 - 73.599 Summer Workshops - Specialized Areas of Pedagogy (1-3)
Concentrated experience in specialized topics of advanced music education pedagogies conducted by visiting or resident experts. Available areas of study are announced for each summer period. Workshops are conducted during two week, all-day intensive sessions.

73.565 Marching Band Techniques (3-0)3
Advanced instruction in organizing and developing a marching band. Exploration of specific philosophies, techniques, and literature; study of computer software applications for marching band design.

73.573 Orff Schulwerk - Level I (3-0)3
Advanced and specialized pedagogical study; Overview of basic Orff Philosophy, techniques, and process; introduction to Orff instrumentarium, movement, and improvisation.

73.574 Orff Schulwerk - Level II (3-0)3
Study of theory involved in the Orff approach; presentation of pentatonic scales and modes; training in irregular rhythms and meters; shifting chord accompaniments, Orff-style composition and arrangement; improvisation.

73.575 Orff Schulwerk - Level III (3-0)3
Continued study of all musical concepts, presentation of functional harmony; orchestration; the complete recorder consort; advanced pedagogy through peer teaching.

73.591 Multicultural Music Education (3-0)3 Focus on the music education profession's response to multiculturalism in education as evidenced through the National Standards and an examination of resources and methodologies for teaching and understanding the music of diverse cultures, styles, and genres.

73.593 Popular Choral Techniques (3-0)3
Practical and effective techniques to aid choral music educators in interpreting, directing, rehearsing and performing repertoire. Includes discussion of vocal improvisation and use of the PA system.

Course Offerings in Performance

72.50l/502 Applied Keyboard IX, X (l/2-10)2

72.5ll/5l2 Applied Voice IX, X (l/2-10)2

72.52l/522 Applied Woodwinds IX, X (l/2-10)2

72.53l/532 Applied Brass & Percussion (l/2-10)2

72.54l/542 Applied Strings IX, X (l/2-10)2

72.55l/552 Performance Keyboard VII, VIII (l-20)4

72.56l/562 Performance Voice VII, VIII (l-20)4

72.57l/572 Performance Woodwinds VII, VIII (l-20)4

72.58l/582 Performance Brass & Percussion VII, VIII (l-20)4

72.59l/592 Performance Strings VII, VIII (l-20)4

72.593/594 Applied Music (l/2-10)2

72.595/596 Applied Conducting I & II (1/2-10)2

72.65l/652 Performance Keyboard IX, X (l-20)4

72.66l/662 Performance Voice IX, X (l-20)4

72.67l/672 Performance Woodwinds IX, X (l-20)4

72.68l/682 Performance Brass & Percussion IX, X (l-20)4

72.69l/692 Performance Strings IX, X (l-20)4

72.693/694 Performance Applied Music (l-20)4

72.695/696 Applied Conducting III & IV (1/2-10)2

75.550 Seminar in Instrumental Conducting Techniques (3-0)3
A study of analytical, rehearsal and baton technique in reference to the instrumental conductor. Program selection, performance practice and artistic interpretation are also included in an interactive seminar format.

75.552 Seminar in Choral Conducting Techniques (3-0)3
A study of analytical, rehearsal and baton technique in reference to the choral conductor. Vocal techniques, program selection, performance practice and artistic interpretation are also included in an interactive seminar format.

75.595 Directed Study and Research in Performance (3-0)3

75.650 Conducting Practicum and Seminar I (3-0)3
An extension of the materials and skills developed in Literature and Techniques Seminars, through practical application, under faculty direction, in conjunction with one or more performing ensembles.

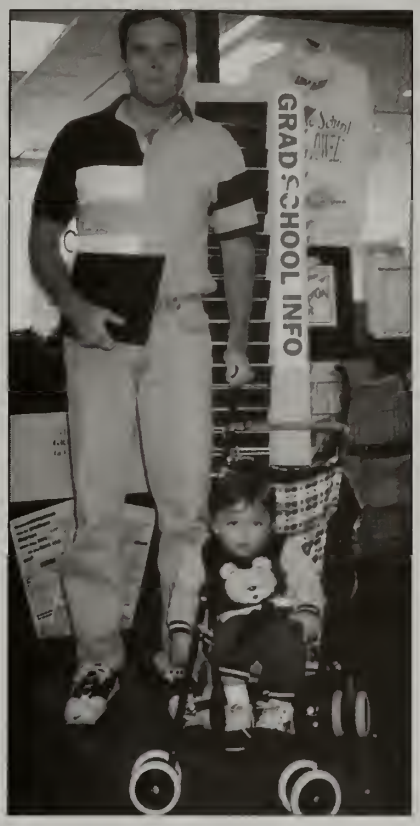
75.652 Conducting Practicum and Seminar II (3-0)3
A continuation of 75.650 to a more advanced level, culminating in the presentation of a public conducting performance and a related analytical document.

75.654 Seminar in Instrumental Literature (3-0)3 A study of stylistic elements, orchestration, formal structure, problem analysis and historical perspective in a selection of standard works from this course.

75.656 Seminar in Choral Literature (3-0)3· A study of style, structure, text and historical perspective in relation to the main body of literature for chorus and orchestra. Independent research is primary element of this course.

75.695 Directed Study and Research in Performance (3-0)3
75.696 Directed Study and Research in Performance (3-0)3
75.796 Directed Study and Research in Performance (3-0)3
76.501 Graduate Vocal Ensemble (0-2)1
76.502 Graduate Instrumental Ensemble (0-2)1
76.601 Graduate Vocal Ensemble (0-4)2
76.602 Graduate Instrumental Ensemble (0-4)2

(Graduate students normally fulfill ensemble participation requirements through membership in a wide variety of College performing organizations, but for credit purposes are registered for only those course numbers listed above).



DEPARTMENT OF PHYSICS AND APPLIED PHYSICS

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James J. Egan
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Graduate Coordinator
Gus Couchell
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Faculty
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Professor Emeritus; B.A., D.Phil., University of Oxford.
George L. Carr
Professor Emeritus; B.S., M.Ed., Western Maryland College; Ph.D., Cornell University.
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Professor Emeritus; B.S., M.S., Lowell Technological Institute.
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Paul J. Ring,
Associate Professor Emeritus; B.S., Boston College; M.S. Rensselaer Polytechnic Institute; Ph.D., Brown University.
Alexander Sachs
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Walter A. Schier
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Richard W. Stimets
Professor; B.S., Ph.D., Massachusetts Institute of Technology.
Jerry Waldman
Professor; B.A., M.A., Columbia University; Ph.D., Massachusetts Institute of Technology.
Martin Wilner
Professor; B.S., Rensselaer Polytechnic Institute; M.S., Yale University; Ph.D., Massachusetts Institute of Technology.
Chuen Wong
Associate Professor; Diploma of Science, Chung Chi College, Hong Kong; Ph.D., Case Western Reserve University.

RESEARCH PROGRAMS

Members of the Department are engaged in research programs in the following areas in which opportunities for advanced degree research are offered: Nuclear Physics, Solid State Physics, Laser Physics, Optics, Submillimeter-Wave Science and Technology, Theory of Elementary Particles, Quantum Field Theory, Atomic Physics, Relativity, Atmospheric Physics, Nuclear and Solar Energy, Applied Mechanics, Computational Physics, Radiological Sciences and Medical Physics.

Areas of study in nuclear physics include high-resolution neutron scattering, fission-product properties, and high-spin nuclear states (work conducted at national heavy-ion accelerators via in-beam gamma-ray spectroscopy). Research equipment includes a 5.5-MeV Van de Graaff accelerator, neutron time-of-flight spectrometer, helium-jet fission-product transfer system, fast neutron irradiation facility, MW nuclear research reactor, 400-kilocurie Co-60 source for gamma-ray irradiation.

Principal areas of optics research include Raman, fluorescence, UV-visible-near-IR spectroscopy, and characterization of nonlinear optical properties of polymeric and semiconductor materials.

Solid state physics and materials science studies include photonic and opto-electronic devices, polymers and biological materials. Research equipment includes an advanced materials characterization laboratory, transmission and scanning electron microscopy, x-ray analysis and surface science facilities, photonics and optoelectronics device development laboratory, molecular beam epitaxy, lithography of thin films and epilayer characterization facilities.

The Submillimeter-Wave Science and Technology Laboratory develops coherent sources, receivers and novel imaging systems for application at terahertz frequencies. Research equipment includes microwave through infrared spectrometers for design and characterization of material dielectric properties, a CO2 and far-infrared laser magnetospectroscopy facility, and submillimeter-wave compact ranges for electromagnetic scattering studies.

Entering Graduate Students

Every entering graduate student is assigned a departmental adviser who will counsel the student on programs of study and other academic requirements, serve as registration officer, help the student to become acquainted with research opportunities in the Department, and assist in selecting a research supervisor. In addition to the requirements for admission listed on page 14 of this catalog, applicants must submit the official test score report for the GRE general test; the Physics subject test is recommended, but not required. Applicants for the M.S. and Ph.D. degrees in Physics are expected to have a sound background in intermediate level mechanics, electricity and magnetism, quantum mechanics, and modern physics. Any student found deficient in any of these areas may be required to take appropriate courses to remove the deficiency.

Students in the Radiological Sciences and Protection M.S. program should have adequate preparation in mathematics, chemistry, physics, biology and nuclear and radiological sciences similar to the undergraduate curriculum in Radiological Health Physics at the University of Massachusetts Lowell.

MASTER OF SCIENCE DEGREE PROGRAM

The Department of Physics and Applied Physics offers Master of Science degrees in Physics and in Radiological Sciences and Protection. The master's program in Physics provides an opportunity for advanced study and research in most of the areas mentioned above, including a M.S. option in Optical Sciences. The master's program in Radiological Sciences and Protection is described elsewhere in this catalog.

Graduate Credits and Course Requirements

At least 30 graduate credit hours are required, of which at least 6 and at most 12 are to be M.S. Thesis Research, or, if an M.S. project is approved by the Department in place of a master's thesis, a maximum of 3 credits of M.S. project research will be allowed. At most, 3 credits of Physics Colloquium and Seminar courses may be applied to the 30 credit requirements.

Candidates for the Master of Science degree in Physics, except those in the Optical Sciences Concentration, are required to complete the following courses:

95.605 Mathematical Methods of Physics I (4-0)4
95.711/712 Garduate Seminar in Physics (1-0)1
95.701/702 Physics Colloquium (1-0)1
Thesis 6-12 Credits or,
Project 3 Credits
4 Electives

Electives may be chosen in consultation with the academic advisor and research supervisor from the list of Physics courses acceptable for graduate credit. Some graduate courses offered by other departments may also be acceptable for graduate credit in Physics, with the approval of the Physics Department. All students are expected to have completed as part of their undergraduate studies a two-semester course in electromagnetic theory (95.553/554 or equivalent) and a two-semester course in introductory quantum mechanics (95.535/536 or equivalent). These courses cannot be counted as one of the 4 Physics electives needed for the M.S. requirement.

Optical Sciences Option

This program is designed to provide the necessary preparation for students wishing to specialize in such rapidly expanding fields as electro-optical phenomena, lasers, applications of optics to telecommunications and information processing, fiber optics and other new optical materials and devices. This option is intended for students who have completed a bachelor's degree program in Physics, Engineering, or other sciences. It is offered in co-operation with the Department of Electrical Engineering which offers an allied option in Opto-electronics. The Optical Sciences option emphasizes laboratory research providing the student valuable "hands-on" experience with optical systems and devices. Two course sequences are available (1) for students with a B.S. in Physics; and (2) for students with a B.S. in Engineering or another scientific discipline.

Course requirements for the Optical Sciences Concentration

For Students with a Physics B.S.

95.605 Math. Meth. Phys. I (4-0)4
95.547 Laser Physics and App. (3-0)3
95.539 Electro-Optics with Lab (3,3)4□
Seminars and Colloquium 3 Credits
Thesis 6-12 Credits or,
Project 3 Credits
2 Electives

For Students with B.S. in other Sciences or Engineering*

95.605 Math. Meth. Phys. I (4-0)4
95.547 Laser Physics and App. (3-0)3
95.539 Electro-Optics with Lab (3,3)4
95.510 Quantum Physics (4-0)4
Seminars and Colloquium 3 Credits
Thesis 6-12 Credits or,
Project 3 Credits
2 Electives

Electives must be chosen from the following list of courses:

95.540 Image Processing & Lab (2-3)4
95.551 Fiber Optics & Lab (2-3)4
95.572 Solid State Physics (3-0)3
95.577/ SS Electronic & Optoelectronic Devices I/II (3-0)3/578(3-0)3
95.615 Quant. Mech I (4-0)4
95.631 Non-Linear Optics (3-0)3
96.547 Experimental Laser Optics (12)2
16.568 Electro-Optics System Design (3-0)3
16.610 Optics for Information Processing (3-0)3

*Assuming adequate preparation in mathematics and electromagnetism.

Colloquia

All full-time master's candidates are required to attend Physics Colloquium, 95.701/702, each semester.

Seminars

All full-time master's candidates are required to take 95.711/712 Graduate Seminar in Physics, in addition to the Colloquium each semester. After a student has presented a seminar in 95.711/712 (s)he may substitute one of the other seminars offered by the Department.

Thesis or Project

The thesis or project is to be based on research performed under the supervision of a member or adjunct member of the Physics Faculty. A student may do a thesis or project under the supervision of a faculty member in another department provided he has a member of the Physics Faculty as a co-supervisor. The student must submit to the Department, for its approval, nine copies of a typewritten proposal briefly describing the project or the problem to be solved for the thesis. This proposal must bear the written approval of the research supervisor. A thesis student must submit the proposal prior to or during the first semester of registration in M.S. Thesis Research in Physics. Students registered for Thesis must submit a brief progress report on the research to the Graduate Coordinator each semester unless a thesis is submitted. Students registered for M.S. Project Research in Physics must submit a final report and complete an oral defense of the Project before the end of the semester. An M.S. Project may not be carried over into a second semester.

After completing the work, thesis students must submit three copies of a typewritten thesis to the Department. The student must then pass an oral examination, administered by a Thesis Committee of the Department appointed by the Graduate Coordinator. The examination will be based upon, but not necessarily restricted to, the subject of the thesis. A student who completes a project rather than a thesis must submit three copies of the final project report to the department and pass an oral examination based upon the subject of the project and upon the subjects all physics M.S. candidates are expected to know (i.e. the subjects in the recommended M.S. course sequence).

DOCTOR OF PHILOSOPHY DEGREE PROGRAM

The Doctor of Philosophy program in Physics and Applied Physics is designed to develop advanced competence in Physics. The Physics course of study prepares the student to carry out original and independent research in physics, while the Applied Physics Options provide training for professional work in several areas of applied physics and allied engineering disciplines.

Graduate Credits

At least 60 graduate credit hours are required, of which at least 15 and at most 24 are to be Ph.D. Dissertation Research. At most 3 credits of Physics Colloquium and seminar courses may be applied to the 60 credit requirement.

Colloquia

All full-time doctoral candidates are required to attend Physics Colloquium, 95.701/702, each semester.

Seminars

All full-time doctoral candidates are required to take at least one physics seminar, in addition to Colloquium, each semester. After a student has presented a seminar in 95.711/712 (s)he may substitute one of the other seminars offered by the Department.

Computer Skills

All candidates are required to demonstrate proficiency in computer programming, which may be accomplished by passing the Departmental computer language exam or by achieving a grade of at least B in courses such as FORTRAN Programming or Introduction to Pascal, or by demonstrating equivalent competence to the Physics Department.

Comprehensive Examination

All candidates must pass a written and oral Physics Comprehensive Examination. Students in pure Physics are expected to take this examination in their first year; those in the Applied Physics options, in their second year. The examination covers I. classical mechanics, II. electricity and magnetism, and III. quantum mechanics, modern physics and statistical mechanics at the advanced undergraduate level. In addition Part I includes some elementary thermodynamics and Part II elementary optics. Part III is replaced by a section on radiological sciences and protection for students in that option and is based on the advanced undergraduate course requirements in Radiological Health Physics.

Graduate Research Admission Examination

Before commencing Ph.D. dissertation research each doctoral candidate must pass two semesters of Advanced Projects in Physics 96.731/732 and defend this project in an oral examination before a committee of the Physics graduate faculty. Students who have already completed a master's thesis in Physics or a related discipline may apply for a waiver of the Advanced Projects requirement. However, if the M.S. degree is from another institution the student must make an oral presentation of the M.S. work before a committee of the Physics Faculty in order to satisfy the Graduate Research Admission Examination requirement. Alternatively, a one-semester M.S. project may be substituded for one semester of Advanced Project on the recommendation of the student's research supervisor. The Graduate Research Admission Examination must be passed before a student may submit a Ph.D. dissertation proposal.

Dissertation

The dissertation is to be based upon original research performed under the supervision of a member or adjunct member of the Physics Faculty (or the Faculty of a Department participating in a joint program with the Physics Department)

holding an earned doctoral degree. If a student wishes to do a dissertation under the supervision of a faculty member in another department, the student must also have a co-supervisor who is a member of the Physics Faculty. Ph.D. candidates must submit to the Department, for its approval, eleven copies of a typewritten proposal briefly describing the research to be carried out. The proposal must bear the written approval of the research supervisor. A student may not register for Ph.D. Dissertation Research, until the Comprehensive Examination and the Graduate Research Admission Examination have been passed. Furthermore, the dissertation proposal must be submitted prior to or during the first semester in which the student is registered for Ph.D. dissertation research. Students registered for Ph.D. Thesis must submit a brief progress report on the research to the Graduate Coordinator each semester unless a thesis is submitted. After completing the work, the student must submit four copies of a typewritten dissertation to the Department. The student must then pass an oral examination, administered by a Dissertation Committee appointed by the Physics Graduate Coordinator, based on, but not necessarily limited to, the dissertation work.

Physics

The following courses are required:

95.605/606 Mathematical Methods of Physics I,II (4-0)(4-0)8
95.611 Classical Mechanics (3-0)3
95.615/616 Quantum Mechanics I,II (4-0)(4-0)8
95.657/658 Electromagnetic Theory I,II (4-0)(4-0)8
95.617 Advanced Quantum Mechanics I (3-0)3
96.731/*Advanced Projects in Physics I,II (3-0)(3-0)6

*This requirement may be waived for students who have written a Master's thesis in Physics or a related discipline.

Electives may be chosen from the list of courses acceptable for graduate credit in Physics. Some graduate courses offered by other departments may also be acceptable for graduate credit in physics, but only with the approval of the Physics Department.

Applied Physics Options

Students in Applied Physics Options may select a program of study and research in one of the following areas:

1. Physics/Energy Engineering Option
   (a) Nuclear Energy
   (b) Solar Energy
2. Physics/Applied Mechanics Option
3. Physics/Radiological Sciences Option

Areas 1, 2, and 3 are official degree program options and will be so noted on the transcript. Areas 1 and 2 are interdisciplinary programs with the Department of Chemical and Nuclear Engineering and with the Department of Mechanical Engineering, respectively. Area 3 is an extension of the Master of Science degree program in Radiological Sciences and Protection.

General Required Courses

Every student in an Applied Physics Ph.D. Option must satisfy the following course requirements:

(a)

95.513 Classical Mechanics (4-0)4
95.553/554 Electromagnetism I,II (3-0)(3-0)6
95.535/536 Intro Quantum Mechanics I,II(3-0)(3-0)6
95.605/606 Mathematical Methods of Physics I,II (4-0)(4-0)8

(b)Six or eight credits from among the following courses, or their equivalents, as appropriate for each option:

95.611 Classical Mechanics (3-0)3
95.521 Statistical Thermodynamics (3-0)3
95.561/662 Nuclear Physics I,II (3-0)(3-0)6
95.615/616 Quantum Mechanics I,II (4-0)(4-0)8
95.617/618 Advanced Quantum Mechanics I,II (3-0)(3-0)6
95.657/658 Electromagnetic Theory I,II (4-0)(4-0)8
95.660 Quantum Mechanics of Many Particle Systems (3-0)3

(c) 96.731/732 Advanced Projects in Physics I,II (3-0)(3-0)6

or the equivalent in the department appropriate to the student's chosen field of concentration. This may be waived for students who have completed a master's thesis.

Physics/Energy Engineering Option

In addition to the general requirements, students in this option must take at least seven additional courses from among the Physics, Energy Engineering, and Mechanical Engineering offerings at the graduate level. These seven courses should include required courses appropriate to either the Solar or Nuclear energy specialization.

Applied Mechanics Option

In addition to the general requirements, students in this option must take at least two graduate courses from the Mechanical Engineering Department, the courses to be determined by the student's academic and research advisors.

Radiological Sciences Option

In addition to the general requirements, students in this option must take the following courses:

95.561/662 Nuclear Physics I,II (3-0)(3-0)6 and at least twelve credits from among the following graduate level Radiological Sciences and Protection courses, assuming the core courses for the Master of Science Degree in Radiological Sciences and Protection have already been completed.

98.522 Envir. Radiation & Nuc. Site Criteria (3-0)3
98.561/562 Special Topics in Radiological Sciences (3-0)3
98.663 Intro. to Radiation Chemistry (3-0)3
98.608 Environmental Toxicology & Epidemiology (3-0)3
98.613 Environmental Monitoring & Surveillance (3-0)3
98.614 External Radiation Dosimetry (3-0)3
98.615 Internal Radiation Dosimetry (3-0)3
98.616 Data Reduction for Rad. Sci. & Protection (3-0)3
98.620 Environmental Impact Statements (3-0)3
98.625 Medical Health Physics (3-0)3
98.646 Accelerator Health Physics (3-0)3
98.651 Intro to Electronic Product Radiation (3-0)3
98.666 Reactor Health Physics (3-0)3
98.681 Medical Physics (3-0)3
98.682 Medical Physics Laboratory (0-9)3

Note: It is expected that the requirements for the Master of Science degree in Radiological Sciences and Protection will be met during the first four semesters if the student has not already earned an M.S. degree.

COURSE DESCRIPTIONS

In the following listings course numbers which are primarily lecture courses with prefix 95 are Physics courses and those with prefix 96 are laboratory courses or research credit courses.

95.513 Mechanics (4-0)4 Prerequisite: 92.234. Particle motion; conservation theorems; rockets; free, damped, and forced oscillations; gravitation; tides; elemets of variational calculus; Hamilton's principle; generalized coordinates; Lagrange's equations; constraints and multipliers' central-force motion; Kepler's problem; system of particles; collisions.

95.521 Statistical Thermodynamics (3-0)3 Prerequisite: 95-335/535. First and second laws of thermodynamics, statistical definition of entropy, definition of absolute temperature, thermal equilibrium of a system in a heat bath; canonical partition function and its applications; thermodynamic potentials; third law of thermodynamics, Carnot cycle, heat engines and refrigerators, phase equilibria and the Clausius-Clapeyron equation and its applications; the heat capacity of solids Einstein's and Debye's models; blackbody radiation and Planck's law for spectral distribution; grand canonical partition function; Bose-Einstein and Fermi-Dirac distributions for ideal gases; the classical perfect gas; ideal Fermi gas and conduction electrons in metals; ideal Bose gas and Bose-Einstein condensation; superfluidity of He II.

95.535 Introductory Quantum Mechanics I (3-0)3 Prerequisite: 95.210 or equivalent. De Broglie waves, the Schroedinger equation, wave functions, wave packets, Heisenberg uncertainty principle, expection values, particle in a box, the simple harmonic oscillator, free particles, step barrier, barrier penetration, square well potential.

95.536 Introductory Quantum Mechanics II (3-0)3 Prerequisite: 95.335/535. The three dimensional Schroedinger equation, the deuteron, angular momentum, spin, the hydrogen atom, spin-orbit interaction, Zeeman effect, Pauli exclusion principle, atomic structure, spectroscopic nomenclature, molecular structure, perturbation theory, transition rate.

95.537 Geometrical Optics (3-0)3 Properties of light, plane surfaces and prisms, thin and thick lenses, mirrors and stops, matrix methods applied to Gaussian (paraxial) optics, Lagrange-Helmholtz invariant, primary and chromatic aberrations, ray tracing and Abbe's sine condition, basic optical instruments including cameras, telescopes, and microscopes. This course may not be used to satisfy the minimum 30 or 60 credits required in any Physics and Applied Physics graduate degree program.

95.538 Physical Optics (3-0)3 Wave nature of light, mathematics of wave motion, electromagnetic theory of light propagation, reflection and refraction, Fresnel coefficients, polarization, interference, Young's experiment, fringe visibility and coherence, various interferometers, Newton's rings and applications, Fraunhofer diffraction by single and multiple apertures and diffraction gratings, Fresnel diffraction. This course may not be used to satisfy the minimum 30 or 60 credits required in any Physics graduate degree program.

95.539 Electro-Optics with Laboratory(3,3)4 Prerequisites: 92.234, 95.338, 96.338. Optical properties of materials, including dispersion, absorption; Reflection and refraction at the boundary of two media; Crystal optics, induced birefringence and optical activity; Polarization states and Jones matrices; Applications to electro-optic devices. Experiments and projects include optical fibers, birefringent crystals, detectors, LED's, Pockel's cell and a fiber optic communication system.

95.540 Image Processing (2-3)4 Prerequisites: 95.238, 95.338.Basic physics of television and other imaging systems: representation and manipulation of images in digital form; Fourier analysis and filtering of images: detection of image features such as edges and regions, pattern recognition, three-dimensional visual perception in man and machine, examples of image processing tasks from such areas as medicine, industrial inspection and robotics, laboratory exercises with an image processing system utilizing an Octec 2000 image analyzer and a Data General Nova 4/C Computer. Ability to program a computer is required.

95-547 Laser Physics and Applications (3-0)3 Prerequisite: 95.335/535. Spontaneous and stimulated emission line broadening processing, rate equations, laser oscillation condition, spectral output of lasers. Gaussian beam propagation and resonator design parameters. Key features of ultraviolet through far infrared laser systems. Application to spectroscopy, radar, welding.

95.551 Fiber Optics (2-3)4 Prerequisite: Permission of Instructor. Introduction to optical communications; basic theory of light guiding; propagation characteristics and focusing effect of an optical waveguide; optical sources and detectors for fiber communications; fundamental parameters of optical fibers, fabrication and testing methods for optical fibers.

95.553 Electromagnetism I (3-0)3 Prerequisite: 92.231. The theory of electromagnetic fields using vector analysis: electrostatic fields and potentials in vacuum, conductors, and dielectric media, magnetic effects of steady currents in nonmagnetic media, magnetic induction and time varying currents and fields.

95.554 Electromagnetism II (3-0)3 Prerequisite: 95.553. Magnetic materials, electric multipoles, solutions to Laplace's equation, boundary conditions, image charge problems, Maxwell's equations; propagation of electromagnetic waves in vacuum, conductors and dielectrics; reflection and refraction of electromagnetic waves; radiation from dipoles and antennas.

95.561 Nuclear Physics I (3-0)3 Prerequisite: 95.336/536 and 95.354/554. Nuclear charge radius, mass, binding energy, moments, parity and statistics; nuclear models: shell model, deformed shell model, collective structure; radioactive decay and counting statistics, time and energy resolution, lifetime measurements; nuclear barrier penetration, alpha decay and systematics, fission.

95.572 Solid State Physics (3-0)3 Prerequisite: 95.421/521. Crystal structures, x-ray and neutron diffraction, lattice vibrations, the free electron and the band models of metals, semiconductors and applications, dielectric and optical properties of solids, magnetism and superconductivity.

95.577 Solid State Electronic and Optoelectronic Devices I (3-0)3 This course is an introduction to solid state electronic and optoelectronic devices for undergraduate science students (i.e. biology, chemistry, mechanical engineering, electrical engineering, physics etc.), graduate students just entering a scientific endeavor which utilizes solid state devices, and practical engineers and scientists whose understanding of modern electronics and optoelectronics needs updating. The course is organized to bring students with a background in sophomore physics to a level of understanding which will allow them to read much of the current literature on new devices and applications. Part I will cover fundamental crystal properties, atoms and electrons, energy bands and charge carriers, excess carriers, junctions and p-n junction diodes (including photo diodes and light-emitting diodes). Three or four practical demonstrations will also be performed with the analysis of the generated data assigned as homework.

95.578 Solid State Electronic and Optelectronic Devices II (3-0)3 This course is a continuation of "Solid State Electronic and Optoelectronic Devices I" and serves as an introduction to solid state electronic and optoelectronic devices for undergraduate science students (i.e. biology, chemistry, mechanical engineering, electrical engineering, physics etc.), graduate students just entering a scientific endeavor which utilizes solid state devices, and practical engineers and scientists whose understanding of modern electronics and optoelectronics needs updating. The course is organized to bring students with a background in sophomore physics to a level of understanding which will allow them to read much of the current literature on new devices and applications. Part II will cover bipolar junction transistors, field effect transistors, integrated circuits, lasers, switching devices, and negative conductance microwave devices. Three or four practical demonstra-

tions will also be performed with the analysis of the generated data assigned as homework.

95.605 Mathematical Methods of Physics I (4-0)4 Vectors, matrices and coordinates, functions of a complex variable, linear differential equations of second order, Fourier series, the Laplace transform, concepts of the theory of distributions, Fourier transforms.

95.606 Mathematical Methods of Physics II (4-0)4 Partial differential equations, special functions, finite - dimensional linear spaces, infinite- dimensional vector spaces, Green's functions, variational methods, traveling waves, radiation, scattering, perturbation methods, tensors.

95.607 Lie Algebras in Particle Physics (3-0)3 Prerequisite: 95.616. Introduction to group theory and its application to high energy physics; definition of a group and its representations; Lie groups and Lie algebras; study of SU(2) Lie algebra, its representations and the Wigner-Eckart theorem; isospin group; roots, weights and simple roots of simple Lie algebras and applications to the SU(3) group; tensor methods for Lie algebras; SU(3) flavor symmetry; Young Tableaux for decomposing products of representations; SU(N) group; SU(6) and the Quark model; the color SU(3) group and the theory of strong interaction of quarks; hadron mass; splittings using group theory; grand unification and the SU(5) group.

95.608 Introduction to Particle Physics (3-0)3 Prerequisites: 95.607 and 95.617. Introduction to quark models; unified gauge theory of weak and e.m. interactions; weak decays of leptons and hadrons; quantum chromodynamics and strong interactions of quarks and gluons; asymptotic freedom; the bound states of quarkonia; the E1 and M1 transitions in quarkonia.

95.611 Classical Mechanics (3-0)3 Prerequisite: 95-513. Review of fundamental principles of mechanics. Central force motion and stability problems. Lagrangian formulation, including Hamilton's principle; Lagrange multipliers. Coupled harmonic oscillators, normal modes. Hamiltonian formulation: Hamilton's equations, finite and infinitesimal canonical transformations, Hamilton - Jacobi method, Poisson brackets, connections among conserved quantities, symmetries and canonical invariants.

95.612 Mechanics of Continuous Media (3-0)3 Prerequisite: 95.513 or 95.611 or equivalent. Continuum mechanics: vibrations of strings; introduction to Lagrangians of continuous systems; introduction to fluid mechanics; sound waves; viscous fluids; surface waves on fluids; introduction to tensor analysis, elastic continua.

95.615 Quantum Mechanics I (4-0)4 Prerequisites: Introductory Quantum Mechanics and 95.605. The representation of quantum states as abstract vectors. Superposition of states. Quantum operators and their matrix representations. Angular momentum operator as the generator of rotations. Eigenvalues and eigenstates of angular momentum. The uncertainty principle. Spin one-half and spin one as examples. Addition of angular momentum. The Hamiltoniaan operator as the generator of time evolution. The Schrodinger equation. Wave mechanics in one dimension: Momentum operator as the generator of translations, eigenstates of position, examples.
Operator solution of the harmonic oscillator.

95.616 Quantum Mechanics II (4-0)4 Prerequisites: 95.615. Wave mechanics in three dimensions: translational invariance and conservation of linear momentum, center-of-mass coordinates, rotational invariance and conservation of angular momentum, position-space representation of the angular momentum operator in spherical coordinates, orbital angular momentum eigenfunctions.

95.617 Advanced Quantum Mechanics I (3-0)3 Prerequisite: 95.616. Dirac equation as a single particle wave equation, free particle spinors and plane waves, matrices and relativistic covariance, nonrelativistic approximation and the fine-structure of the H atom. Quantization of the e.m. field in the coulomb gauge; interaction of an atom with the quantized radiation field; radiative transitions in atoms; Thomson scattering; classical and quantized Lagrangian field theory; Symmetries and conservation laws; quantization of the real and complex Klein-Gordon field; Dirac Field and the covariant quantization of the e.m. field; Feynman propagators; the interaction picture and the S-matrix expansion in perturbation theory and the Wick's Rule. Feynman diagrams and rules for calculating S-matrix elements in QED; formulas for cross-section and spin and photon polarization sums; calculation of cross-sections for (1)e+ + e- --> l+ + l- (2) e+ + e- --> e+ + e- (3) Compton scattering and (4) scattering of electrons by an external e.m. field.

95.618 Advanced Quantum Mechanics II (3-0)3 Prerequisite: 95.617. Radiative corrections to processes in quantum electrodynamics; mass and charge renormalization; dimensional regularization; vacuum polarization; anomalous magnetic moment of the electron and the Lamb-shift; unified gauge theory of electro-weak interactions; W and Z bosons and their properties; introduction to quantum chromodynamics.

95.631 Non-linear Optics (3-0)3 Brief review of linear optics and optical waves in anisotropic linear media. Wave propagation in nonlinear media. Acousto-optics. Second order nonlinear optical phenomena: sum and difference frequency generation, parametric amplification, Pockels effect and electro-optic modulators based on them. Third order nonlinear optical phenomena: third harmonic generation, stimulated Raman scattering, stimulated Brillouin scattering, intensity dependent refractive index and Kerr effect. Magneto-optical phenomena and the physics of photorefractive materials.

95.632 Integrated Optics (3-0)3 Planar optical waveguide modes. Wave guide fabrication methods. Losses in optical wave guides. Input and output couplers. Coupling between wave guides. Electro-optics and acousto-optic modulators. Semiconductor lasers and detectors.

95.657/658 Electromagnetic Theory I,II (4-0)(4-0)8 Prerequisite: 95-606. Electrostatics and magnetostatics with special attention to boundary value problems. Quasistatic fields and displacement currents. Maxwell's equations, special relativity, waveguides, scattering, radiation from accelerated charges, propagation in material media and plasmas, Kramers-Kronig relations.

95.660 Quantum Mechanics of Many Particle Systems (3-0)3 Prerequisite: 95.616. Non-relativistic quantum mechanics of many-particle systems, having application to many-electron atoms, molecules, condensed matter and nuclei. Selection of topics varies and may include Hartree-Fock and Fermi-Thomas and their modern descendants: X-alpha, Green's Functions, Feynman graphs, density functionals; applications of group theory to symmetric clusters of atoms.

95-662 Nuclear Physics II (3-0)3 Prerequisite 95.561. Theory of beta and gamma decay and selection rules, angular correlations; nuclear reaction kinematics, reaction mechanisms, partial wave analysis of scattering, heavy-ion reactions.

95-673/674 Advanced Theory of Solids I, II (3-0)3 Prerequisite: 95-616. Lattice vibrations and their interactions with X-rays, neutrons and light. The band model of solids and energy band calculations; the Fermi surface. Transport and optical properties in metals and semiconductors. Magnetism and magnetic resonance; superconductivity. Many-body theory and applications; collective excitations; Green's function techniques in solid state physics.

95-675/676 Neutral Particle Transport I,II (3-0)(3-0)6 Boltzmann and integral transport equations. Spherical harmonic and variational methods, special methods of solving transport equations. Corrections to diffusion theory. Adjoint functions. Applications.

95-683/684 General Theory of Relativity I,II (3-0)(3-0)6 Review of Newtonian gravitational theory and special relativity. Principles of equivalence. Tensor analysis in Riemann spaces. Einstein's field equations; tests of Einstein's theory. Spherically symmetric solutions. Applications in astrophysics and cosmology.

95-686 Semiconductor Physics (3-0)3 Prerequisite: 95-472/572. Transport and optical properties of semiconductors. Statistics, collision mechanisms, effective mass theory, donors and acceptors. Hot electrons. High magnetic field phenomena. Devices: junctions and transistors. Gunn oscillators; semiconductor lasers.

95-701/702 Physics Colloquium (1-0)(1-0)2 A series of invited lectures on current research topics in Physics.
95-703/704 Seminar in Nuclear Physics (1-0)(1-0)2
95-705/706 Seminar in Solid State/Optics (1-0)(1-0)2
95-707/708 Seminar in Theoretical Physics (1-0)(1-0)2
The preceding three seminars involve presentations by students, faculty members, and visiting scientists of advanced topics, original research or journal articles.
95-709 Seminar in Accelerator Physics (1-0)1 Prerequisite: Permission of Instructor. A weekly series of presentations and discussions by students and faculty concerning research in progress and planned research at the 5.5 MV Van de Graaff Accelerator. Enrollment in the course is limited to students whose research projects involve the Van de Graaff accelerator.
95-710 Seminar in Experimental Optics (1-0)1 Prerequisite: Permission of Instructor. A weekly series of presentations and discussions concerning experimental optics research in the University of Massachusetts Lowell Department of Physics and Applied Physics.
95-711/712 Graduate Seminar in Physics (1-0)(1-0)2 Presentations by students of progress in their research projects.
95-721/722 Selected Topics in Physics (3-0)(3-0)6
95-723/724 Selected Topics in Nuclear Physics (3-0)(3-0)6
95-725/726 Selected Topics in Solid State Physics (3-0)(3-0)6
95-727/728 Selected Topics in Theoretical Physics (3-0)(3-0)6 The preceding selected topics courses cover recent advances and more advanced topics, not covered in the regular courses in these areas. Subject matter varies, depending on the interests of the instructor and the needs of the students. Subject matter varies sufficiently that these courses may be taken more than once for credit without repeating topics.
96.593 Graduate Physics Laboratory (0-4)2 Experiments in various branches of physics including optics, atomic physics, solid state physics and nuclear physics.
96.713/716/719 Special Problems in Physics (0-9)3,(0-9)6,(0-27)9 Prerequisite: Written Permission of Supervisor. Reading in preparation for research, or research not for thesis. If results of the research are to be subsequently incorporated into a thesis, credits earned in this course may be used to satisfy thesis credit requirements in M.S. or Ph.D. Thesis Research with the written permission of the thesis supervisor, provided such permission is granted at the time of registration for this course. If the results are incorporated in an M.S. project, not more than 3 credits are allowed.
96.731/732 Advanced Projects in Physics I,II (3-0)(3-0)6 Prerequisite: Written Permission of Supervisor. Research project leading to the Graduate Research Admission Examination (for Ph.D. candidates only.)
96.733 M.S. Research Project in Physics (0-9)3 Prerequisite: Departmental approval of an M.S. Project proposal and written permission of supervisor.
96.743/746/749 M.S. Thesis Research in Physics (0-9)3,(0-18)6,(0-27)9 Prerequisite: Departmental approval of an M.S. Thesis proposal and written permission of supervisor.
96.753/756/759 Ph.D. Dissertation Research in Physics (0-9)3,3(0-18)6,(0-27)9 Prerequisite: Departmental approval of a Ph.D. dissertation proposal and written permission of supervisor. Note: Courses with 98 prefix are described in the Radiological Sciences and Protection section of this catalog.

DEPARTMENT OF PSYCHOLOGY

Department Chair
Charlotte Mandell
Professor; B.A., Brooklyn College; M.A., Ph.D., Columbia University.

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Faculty
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Joan B. Cannon
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Jon Hellstedt
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Professor; A.B., Northwestern University; Ed.M., Boston University; C.A.G.S., University of New Hampshire; Ed.D., Boston University.
Robert Kunzendorf
Professor; B.A., Yale University; M.A., Ph.D., University of Virginia.
David Landrigan
Associate Professor; B.S., Tufts University; M.A., Ph.D., University of New Hampshire.
Allyssa McCabe
Associate Professor; A.B., Oberlin College; M.A., Ph.D., University of Virginia.
Anne Mulvey
Professor; B.A., Barat College; Ph.D., City University of New York.
Charles Nikitopoulos
Associate Professor; A.B., Suffolk University; M.A., New School for Social Research; Ph.D., Boston College.
Ronald M. Pickett
Professor; A.B., Dartmouth College; M.A., Ph.D., University of Michigan.
Gloria Seeman
Associate Professor; B.A., City College of New York; Ph.D., Syracuse University.
Richard Siegel
Associate Professor; A.B., Harvard College; M.S., Yale University; Ph.D., Boston University.
Linda Silka
Professor; B.S. Oklahoma State University; M.A., Ph.D., Kansas University.
Joseph Waterman
Associate Professor; B.S., University of Vermont; M.B.A., Boston University; P.Ed. University of Connecticut.

MASTER OF ARTS IN COMMUNITY SOCIAL PSYCHOLOGY

Philosophy and Objectives of the Program

Community social psychologists study relationships between social and environmental forces and the psychological well-being of people. They seek to understand how individuals and groups are affected by such social influences as employment and educational opportunity, organization and delivery of public services, and the social systems within which people live and work.

The M.A. program in Community Social Psychology provides students with a rich understanding of how communities and organizations influence behavior, adjustment, and growth. Students graduate knowing how to analyze and solve human problems in a wide variety of community settings. An emphasis on facts, methods, values, and especially practical skills creates a dynamic learning experience. This is one of the few M.A. programs of its kind in the Northeast. All students gain:

- Knowledge about how social and environmental factors affect the individual
- Proficiency in conducting applied research and performing data analysis
- Increased awareness of multiculturalism, human diversity, and social justice issues.
- Ability to design, implement, and evaluate community programs.

This graduate program meets the needs of students from various academic and occupational backgrounds. It attracts recent undergraduates from such fields as Psychology, Sociology, Political Science, Health, and Education. For those already working, it enhances the skills and career development of human service workers, community developers, health care providers, teachers, government employees, human resource professionals, administrators, and managers in a wide variety of public and private sector positions. Employment opportunities for graduates of the program, both in the nonprofit and private sectors, have traditionally been very strong.

Admission Requirements

The Community Social Psychology program at the University of Mass-

achusetts Lowell is designed not only for recent college graduates but also for older and non-traditional students with experience in a variety of work and community settings. The requirements for admission include the following:

1. Official evidence of having earned a bachelor's degree or U.S. equivalent from an accredited college or university.

2. An undergraduate average of "B" or better in the field of psychology or a related major. Students from other major fields are invited to apply, but may be asked to complete some undergraduate requirements. All applicants should have completed a basic statistics or research methods course; students lacking this prerequisite must fulfill this requirement prior to matriculation.

3. Acceptable performance on the Graduate Record Examination Aptitude Test, or on the Miller Analogies Test.

4. Three letters of recommendation related to the applicant's educational and professional qualifications. Inclusion of letters from former academic instructors is strongly recommended.

5. A personal letter including a statement about the applicant's professional interests, educational and work qualifications, and future goals.

6. Prospective candidates may be requested to participate in an interview with members of the program's Student Affairs Committee.

Transfer Credit

Matriculated students in Community Social Psychology are allowed to transfer up to 10 credits of course work completed at other accredited universities, provided that such courses are within the content area of community social psychology and do not involve credit for field experience or professional work. Such transfer credit is subject to the approval of the Student Affairs Committee and the Graduate School.

B.A./M.A. Option

Undergraduate psychology majors at the University of Massachusetts Lowell may apply for the B.A./M.A. option, allowing students to accelerate completion of the Master's degree. Additional information on the B.A./M.A. option is available from the Graduate Coordinator.

Part-time Study and Non-Degree Status

While the program in Community Social Psychology provides for full-time study, part-time students are encouraged to apply. In fact, the majority of students complete their program on a part-time basis. Courses are offered at late afternoon and evening hours to accommodate students who are employed.

Students not pursuing an advanced degree or who wish to begin their graduate study without first applying for matriculated status are invited to register as non-degree students for specific graduate courses on a space-available basis. Such students need meet only the first two of the admissions requirements listed above.

If a non-degree student later applies for acceptance into the Master's program, his/her application will be treated equally with those of other new applicants, though performance in graduate courses taken on campus may be used as an additional admissions criterion. Non-degree students accepted as matriculated students may apply to transfer a maximum of 12 graduate credits earned at the University of Massachusetts Lowell with a grade of "B" or better toward the Master's degree.

Graduate Advisor

Each newly-matriculated student in the program will be assigned to an advisor from among the faculty of the graduate program. The student will meet with his/her advisor on a regular basis throughout the years of study to discuss course selections, planning for practicum, and the development of the thesis or project. Once a student selects a faculty supervisor for his/her thesis or project, this faculty member takes over as graduate academic advisor.

Degree Requirements: Credits

A total of 36 academic credits, at least 26 of which must be taken at the University of Massachusetts Lowell with a grade average of "B" or better, is required for the completion of the degree. The 36 credits for the Master's degree are divided as follows:

Required Coursework (includes 47.512 and 47.520)	12 credits
Required Practicum	6 credits
Thesis Option	6 credits
or	
Project Option	3 credits
Electives	12, 15, or 18 credits
Total must equal	36 credits

Students are encouraged to participate actively in tailoring their program to achieve specific career and professional goals. Specialization within specific subareas is possible. This may be done through careful selection of coursework, independent study, practicum, and thesis or project experience. A limited number of approved courses taken outside the department may count as electives when these strengthen a student's identified area of interest.

Thesis and Project Options

Each student in the program must complete a capstone experience to demonstrate mastery of the concepts of community and social psychology. The two options of thesis and project are available to allow each student to shape the capstone experience to meet his or her professional goals.

The thesis or project is an original piece of work in the student's area of specialization. The thesis (6 credits) is a faculty-supervised research activity; the project (3 credits) is a faculty-supervised change-oriented activity. Each provides an opportunity for the student to demonstrate skills and knowledge acquired in the program and to make an original contribution to the field of community social psychology. Students may register for 3, 6, or 9 credits in 47.743 (Thesis) or 3 credits in 47.733 (Project) while doing thesis or project work. No more than 6 credits of 47.743 or 3 credits of 47.733 can be counted toward the 36 credit degree requirement.

Students typically initiate the thesis/project after completion of 12 to 18 credits. Additional information about the thesis and project requirements is available through the Graduate Coordinator.

RESOURCES

The Center for Family, Work, and Community

The goal of The Center for Family, Work, and Community is to promote the mental health and well-being of individuals, families, and communities through education, training, and consultation. Its aim is to provide opportunities for University of Massachusetts faculty, community members, and practicing professionals to work together to integrate theory, research, and practice. The Center sponsors community-based training, professional development workshops, consultation, and research.

Flowering City Forum

This initiative is an Internet-based community network. Flowering City Forum (FCF) supports the city's comprehensive environmental improvement project, Lowell: The Flowering City, by (1) providing news and information about the project; (2) facilitating local dialogue about environmental and community development efforts; and (3) generating creative expression about the city's unique cultural heritage and natural resources while empowering artists, humanists, interpretive scientists, educators, and cultural organizations in the use of advanced technology.

Laboratory for Children and Families

The Laboratory for Children and Families is located in the Department of Psychology at the University of Massachusetts Lowell. The Laboratory provides a site for research on the development of infants and children in the context of their families and communities.

Center for Women and Work

The Center for Women and Work is an interdisciplinary center at the University of Massachusetts Lowell. Since the Center is designed to support a wide range of projects, there are exciting opportunities for student involvement in both research and community-based action projects relevant to the theme of women and work.

CERTIFICATE PROGRAMS

Domestic Violence Studies

Domestic Violence is one of the major social problems facing residents of the Commonwealth. Students hoping to enter and those already working in nursing, health, social services, youth services, police, hospital and health agency administration, etc. gain expertise in the prevention of and response to domestic violence. The certificate will be sponsored by the Departments of Criminal Justice and Psychology with the cooperation of the College of Health Professions.

Job Stress and Healthy Job Redesign

The increasing importance of stress-related problems in the workplace is indicated by the rapidly rising levels of worker's compensation cases with job stress components. Identification of hazards builds on multi-disciplinary understanding of the stress development process at the workplace. Prevention techniques include monitoring strategies, training, communication strategies, and redesign of the organizational and technical aspects of work processes.

Qualifications: Bachelor's degree in the social sciences, health sciences, health and managerial professions, natural sciences, or engineering; significant work experience. Further information about the Master's program, certificate programs and procedures for applying to each may be obtained by contacting the Graduate Coordinator.

COURSE DESCRIPTIONS

47.501 Applied Developmental Psychology (3-0)3 Provides a life span developmental perspective on individual and social adaptation and change. Examines appropriate theory and research, and illustrates the influences of environmental, social and cultural factors.

47.502 Seminar in Community and Social Psychology (3-0)3 This course is designed to acquaint the student with new developments from a broad range of current psychological theory and research and how these developments might affect social and community life.

47.503 Applied Social Psychology (3-0)3 Introduces students to social psychology as an applied discipline. Covers such applied topics as attitude change, aggression, helping behavior, attribution, and interpersonal influence.

47-504 The Family System (3-0)3 Studies family processes and the interplay between the family and other social, cultural, and socio-economic systems. Topics include parental roles, changing family structures, racial and ethnic factors, and interactions between family, work, and community.

47.511 Helping Skills I: Dyads (formerly Community and Social Aspects of Counseling) (3-0)3 The basics of the helping relationship with individuals are covered, including interviewing, listening, basic and advanced empathy, goal setting, and implementing strategies for change. The emphasis will be on the dyadic relationship of helper and client, though some applications to larger networks will be covered. The emphasis will be on how to use these techniques in human service settings in the community.

47.512 Applied Research Methods (3-0)3 Considers strengths and limitations of various approaches to community and social psychological research. Develops skills for formulating research questions and translating them into practical study designs. Sensitivity to research ethics as well as research practicality and validity are emphasized.

47.513 Helping Skills II: Groups and Organizations (formerly Communication in Human Organizations) (3-0)3 In this course the student will be exposed to skills in leading groups and consulting to community groups and organizations. The course will cover group and organizational dynamics, leadership skills, conflict resolution, problem solving, goal setting, and program planning.

47.520 Introduction to Community and Social Psychology (3-0)3 Introduces history and contemporary trends of community and social psychology with focus on how social and environmental forces affect individual and group quality of life. Surveys issues, methods, and applications.

47.523 Women in the Community (3-0)3 An examination of women's roles in the home, community, and work place; examines psychological consequences, social structural influences, and options for change. Topics include: housework and childcare; violence against women; work place stratification issues; and women's contributions to their communities.

47.524 Ethnic and Racial Factors in the Community (3-0)3 Examines the multi-ethnic community and its effects on behavior, with major emphasis on conflict, prejudice and accommodation, as applied to a variety of social settings, including community, institutional, and industrial contexts.

47.525 Psychology of the Mid-Sized City: Lowell (3-0)3 Lowell serves as a model for examining the social issues and systems of mid-sized cities. The course considers how diversity, revitalization, neighborhoods, housing, education, and industry affect quality of life.

47.551 Psychosocial Aspects of Maturity and Aging (3-0)3 Covers changes in behavior from adulthood to old age with emphasis on changes in personality, mental health, sensation and perception, intelligence and learning, and those individual, situational, and cultural variables that contribute to successful aging.

47.611 Program Evaluation (3-0)3 A skill-oriented approach that considers both formative and summative evaluation techniques. Emphasizes mastery of the technical aspects of the evaluation process.

47.621 Social System Dynamics: Intervention and Change (3-0)3 Examines the structure and dynamics of mental health, educational, medical, industrial, and other systems with emphasis on strategies, theories, and ethics of social change.

47.622 Selected Topics in Community and Social Psychology (3-0)3 Advanced topics in various areas of Community and Social Psychology. Offered regularly, reflecting special interests of the faculty and students, and may be repeated for credit.

47.631 Practicum I (3-12)3

47.632 Practicum II (3-12)3

Provides supervised field experience in a setting appropriate to the student's area of specialization, plus on-campus class meetings. Nine to twelve hours of field work a week for two semesters are required. Students begin the Practicum upon completion of 12 and no more than 18 credits.

47.691 Directed Study in Community and Social Psychology (3-0)3 This course is designed as an independent study of a subject not offered in the standard curriculum.

47.733 Master's Project in Community-Social Psychology (3-0)3 Prerequisite: Approval of major advisor. For graduate students actively engaged in developing a change-oriented intervention leading to the submission of a written project report. A program of supervised study will be arranged between the student and a faculty supervisor.

47.743 Master's Thesis in Community Social Psychology Prerequisite: Approval of major advisor. (6-0)6 For graduate students actively engaged in research leading toward the submission of a written thesis. A program of supervised study will be arranged between the student and a faculty supervisor. This course may be repeated for credit, but only a total of 6 credits may be counted toward the Master's degree.

DEPARTMENT OF PHYSICS
RADIOLOGICAL SCIENCES AND PROTECTION

Graduate Coordinator

Clayton S. French
Professor; B.S.,Lowell Technological Institute; M.S., Ph.D., University of Lowell; (C.H.P.).

Faculty

George E. Chabot
Professor; A.B., Harvard University; M.S., Harvard School of Public Health; Ph.D., University of Lowell; (C.H.P.).

Kenneth W. Skrable
Professor Emeritus; B.S., Moravian College; M.S.,Vanderbilt University; Ph.D., Rutgers-The State University; (C.H.P.).

Jesse Y. Harris
Professor Emeritus; B.S., M.S., Ph.D., Rutgers-The State University.

MASTER OF SCIENCE DEGREE PROGRAM

With the prevalent use of radiation and radioactive material in society, there is a continuing need for research and advanced education in Radiological Sciences and Protection. The excellent facilities, equipment and supporting staff available at the University of Massachusetts Lowell's Radiation Laboratory and faculty in the Radiological Sciences Program and in other allied departments give students at the University of Massachusetts Lowell (UML) a unique opportunity to obtain rewarding careers in and make significant research contributions to the radiation protection field. The Master of Science Degree Program in Radiological Sciences and Protection is interdisciplinary in nature and should be attractive to engineering students and students in the biological and physical sciences.

The Profession of Radiological Health Physics

Radiological Health Physics (RHP) involves the study of the effects of radiation and radioactivity on life processes. It also can be called radiation protection science and is particularly involved with the effects of radiation on the human body and the control of such radiation. A graduate of this curriculum at the University of Massachusetts Lowell (UML) would enter the profession of health physics, which is devoted to the protection of man and the environment from the harmful effects of radiation while at the same time making it possible for our advancing civilization to enjoy all of the benefits resulting from uses of radiation.

Radiation control in its professional aspects requires the skills and knowledge from many disciplines. It has common scientific interests with many areas of specialization: biophysics, physics, biochemistry, chemistry, biology, genetics, ecology, nuclear engineering, metallurgy, medicine, physiology, industrial hygiene, and toxicology. Other aspects of the profession include a working knowledge of labor relations, public relations, teaching, philosophy, and administration. The wide spectrum of knowledge required of the health physicist makes this profession both challenging and rewarding.

Employment and Scholarship Opportunities

Health physicists are employed by federal agencies (such as the Nuclear Regulatory Commission and Department of Energy) at research, production, and testing facilities; state, and local government agencies responsible for regulating the use of radiation sources and radioactive materials; the military services; electric utilities operating nuclear power plants and many related industries such as engineering support companies; industries which use radioisotopes or x-ray equipment to detect flaws or defects in manufactured products, prepare or reprocess nuclear fuels, control nuclear wastes, or produce or use radioactive materials or devices; universities (in teaching, research, and equipment monitoring); hospitals and medical centers that use radionuclides, x-ray equipment, and accelerators in the diagnosis and treatment of patients; and consulting firms which advise the organizations that do not employ full-time health physicists.

Scholarships are available for graduate students who choose the Radiological Sciences Program. These are available from the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), the National Academy for Nuclear Training, the Health Physics Society (HPS), the American Nuclear Society (ANS), and other organizations concerned with radiation protection. Teaching Assistantships and Research Assistantships are available on a limited basis for UML graduate students.

Students may gain valuable applied work experience while also earning graduate credit and money through various summer internship programs. They also may gain experience and academic credit through an internship course at the UML Radiation Laboratory. This course is conducted under the direction of the health physics staff who have responsibility for the radiation safety programs at the nuclear reactor facility; accelerator facility, radioisotope research laboratories and x-ray facilities at the University of Massachusetts Lowell.

Admission Requirements

In addition to the requirements for admission listed on page 14 of this catalog, a student should have a reasonable minimum preparation, including courses in mathematics, chemistry, physics, biology and in nuclear and radiological sciences similar to the undergraduate curriculum in Physics/Radiological Health Physics Option at the University of Massachusetts Lowell. Because there is no advanced test in the field of Radiological Sciences and Protection, and because various undergraduate backgrounds are suitable for graduate study in the program, students are not required to take the Advanced GRE tests. The GRE Aptitude Test, however, is required. It is important that the mathematical preparation of students include differential and integral calculus through differential equations.

Plan of Study

The program allows a student to select courses and a research project consistent with his/her desired area of professional development. Various opportunities for research and professional development are possible through the use of the Radiation Laboratory of the University and through cooperative programs with hospitals, nuclear reactor facilities, government laboratories, and other radiation facilities. A research advisor, other than a University of Massachusetts Lowell faculty member, may be approved for the conduct of research at facilities outside the University. Two M.S. degree options are available: thesis option or project option. In addition to a core curriculum, a master's thesis or project report must be submitted and approved.

Thesis Option

Under the thesis option, a student must complete a minimum of 21 credits of formal courses and a minimum of 9 credits of graduate research. The master's thesis generally will consist of a scholarly laboratory or theoretical investigation in the field of Radiological Sciences and Protection. Proposed research must be approved by the Program Graduate Committee. The format for the final written thesis shall conform to the requirements of the Graduate School. The thesis proposal and report requirements may be obtained from the Program Coordinator.

Project Option

Under the project option, a student must complete a minimum of 27 credits of formal courses and 3 credits of graduate research to yield a total of 30 credits. In addition to the project report, the student must pass a comprehensive examination. The master's project consists of a scholarly investigation such as a review, report, design, etc., in the field of Radiological Sciences and Protection. The subject of the project must be approved by the student's advisor in advance. The final report must be approved by the Program Graduate Committee and conform to the format specified by the Graduate School.

Oral Defense of Thesis

A thesis committee is appointed to read a student's thesis and to listen to an oral presentation and defense by the student. In general, the committee will include the thesis advisor and two additional members chosen from the Physics faculty or from other departments in which the candidate has taken graduate studies.

Comprehensive Examination for the Project (Non-Thesis) Option

Degree candidates electing the project option are required to pass a Comprehensive written examination administered by the Program Graduate Committee. This examination normally will be administered during the semester in which the student completes his/her course requirements for the M.S. degree. The comprehensive examination may be waived for a student who can document that he/she has passed Part I of the American Board of Health Physics Certification Examination.

Residency and Foreign Language Requirements

No residency or foreign language requirements are specified by the Department.

Core Curriculum

A core curriculum consisting of seven courses and Thesis Research or Graduate Project in Radiological Sciences and Protection are required of all students pursuing the Master's Degree in Radiological Sciences and Protection. These core courses are listed below along with other courses offered by the Department for graduate credit. If a student has already had a course or courses similar to those listed, then the requirement for such courses may be waived. Courses in Nuclear Engineering, Physics and Applied Physics, Environmental Studies, Biology, Mathematics, Meteorology, Chemistry, Work Environment, and others may be selected for graduate credit with the approval of the Department.

Required Core Courses

98.506 Nuclear Instrumentation † (4)
98.555 Physics of Radiation and Nuclei (3)
98.501 Radiation Safety and Control I (4)
98.502 Radiation Safety and Control II (4)
98.533 External Radiation Dosimetry and Shielding (3)
98.534 Internal Radiation Dosimetry and Bioassay (3)
98.562 Radiation Biology (3)
98.711 Graduate Seminar in Radiological Sciences and Protection (1)
98.712 Graduate Seminar in Radiological Sciences and Protection (1)
98.733 Graduate Project in Radiological Sciences and Protection (3)
98.743 MS Thesis Research in Radiological Sciences and Protection (3, 6, 9)

† 96.260 Physical Instrumentation (2 cr) or equivalent is a prerequisite.

FIVE YEAR B.S./M.S. DEGREE PROGRAM

A five-year B.S./M.S. program is available to well qualified undergraduates. For information, see the description at the front of this catalog.

Graduate Radiological Science & Protection Internships

It is highly desirable that every graduate of the Radiological Science and Protection program have work experience in a field of specialization. Students may receive academic credit for volunteer or paid work experience that meets the guidelines established by the program graduate committee. Students are permitted to register for only one internship course during a semester. A minimum of 135 hours of applicable and satisfactory work experience is required during the semester to receive a passing grade. No credit is allowed for work experience gained prior to registering for the course. A maximum of 3 credits of internship courses may be applied toward the minimum of 30 credits required for the M.S. degree, and a maximum of 6 credits may be applied toward the Ph.D. requirements. Only matriculated students may register for internship courses, and the student is allowed to register for a total of no more than two internship courses.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM

See Physics and Applied Physics section in this catalog.

COURSE DESCRIPTIONS

98.501 Radiation Safety and Control I (3-3)4 Prerequisite: 98.555 or equivalent. Introduction to radiation protection, including sources of radioactivity, radiation types and characteristics, energetics, kinetics, radiation interactions, radiation dose quantities, external and internal radiation dosimetry concepts.

98.502 Radiation Safety and Control II (3-3)4 Prerequisite: 98.501. A laboratory course giving students experience with equipment and practices used in the radiation protection field; an extension of 98.501 giving some of the practical aspects of radiation safety and control including radioactivity analyses and measurement, radiation shielding, air sampling and analyses, and radiation protection standards and regulations.

98.506 Nuclear Instrumentation (3-3)4 Prerequisites: 98.555, 96.260. Operating principles and applications of nuclear radiation detectors, associated electronic signal processing equipment, data analysis techniques. Topics covered include charged-particle, photon, and neutron detection, plus charged-particle and gamma-ray spectroscopy. Use of scintillators, photomultiplier tubes, solid state detectors, gas-filled counters, oscilloscopes, etc.

98.514 Advanced External Radiation Dosimetry (3-0)3 Prerequisite: 98.533 or permission of instructor. A more detailed discussion of selected topics introduced in 98.533; the relationships among primary ionizing radiations (photons, charged particles, and neutrons) and secondary charged particles responsible for dose; effects of scatter on fluence and energy distributions of secondary radiations; cavity theory as applied to dose measurement using ionization chambers; calibration of radiation fields; elements of microdosimetry.

98.516 Advanced Internal Radiation Dosimetry (3-0)3 Prerequisite: 98.534 or permission of instructor. Extensions of concepts and problem solving techniques introduced in 98.534 to the evaluation of internal dosimetry and bioassay problems. A brief review of mathematical modeling of intakes of and doses from internally deposited radionuclides will be presented, but major emphasis will be on approches to solving a variety of real world problems involving exposures by inhalation, ingestion, and skin penetration to various radionuclides, including fission products, activation products, uranium and transuranic radionuclides.

98.522 Environmental Radiation and Nuclear Site Criteria (3-0)3 Prerequisite: Introductory Course Covering Basic Nuclear Concepts. Study of sources, distribution, environmental transport and dose projections of environmental radionuclides. Emphasis on environmental impact of nuclear fuel cycle.

98.533 External Radiation Dosimetry and Shielding (3-0)3 Prerequisite: 98.502. Major elements of ionizing radiation dosimetry and shielding for photons, charged particles, and neutrons; ICRU quantities and units; charged particle equilibrium and energy spatial equilibrium; relationship between kerma and absorbed dose; primary photon transmission and secondary photon buildup; analysis of effects of varying source geometries; neutron removal cross sections and applications; transport techniques; shielding of medical x-ray facilities and shielding of accelerators.

98.534 Internal Radiation Dosimetry and Bioassay (3-0)3 Prerequisite: 98.502. Approaches to evaluation of intakes and committed doses from internal deposition of radionuclides; physiological and metabolic considerations for reference man; ICRP and MIRD models and methodologies; intake and retention functions; excretion functions and analysis of bioassay samples; recycling of radionuclides among body tissues; bioassay data evaluation; regulatory requirements.

98.541 Radiochemistry (3-0)3 Prerequisite: Permission of instructor. This course stresses analytical techniques applicable to identification and quantification of radionuclides in various sample types. Considerable time will be spent on review of general chemistry and inorganic analytical chemistry. The theories and applications of various separation techniques including precipitation, solvent extraction, ion exchange chromatography, and electrodeposition will be discussed with emphasis on separation of radioactive species. Additional material to be covered includes instrumental techniques for analysis of radioactive species, radiotracer and isotope dilution techniques, saturation activation analysis, and sample preparation.

98.543 Radiochemistry Laboratory (0-3)1 Corequisite: 98.541. This laboratory course will require the completion of between 4 and 6 separate laboratory procedures and participation in 2 to 4 demonstration sessions. Laboratories will stress various analytical techniques for determination of specific radionuclides. At least two laboratory sessions, which may extend more than one period, will deal with analysis of environmental samples of specific radionuclides. A variety of separation procedures including precipitation, solvent extraction, ion exchange chromatography, gas deemanation, and electrodeposition will be employed.

98.551/552 Special Topics in Radiological Sciences (3-0)3 This course is used to provide students with current information on topics of interest to graduate students in

Radiological Sciences and Protection. Topics covered may vary from year to year. Topics are announced prior to registration.

98.555 Physics of Radiation & Nuclei (4-0)4 Prerequisite: 95.144 or equivalent. A survey of atomic and nuclear physics directed to an understanding of the basic modern physics utilized in radiological science and nuclear engineering. Materials covered includes, but is not limited to, the following topics: Classical and relativistic relationships for momentum and energy, mass energy relationships, motion of charged particles in charged and magnetic fields, mass and charge of electron, atomic mass and isotopes, the photon, photoelectric effect, the Compton effect, wave particle dualism and probability, absorption of photons, scattering and cross sections, Rutherford's nuclear atom, atomic spectra and Bohr's theory of the hydrogen atom, emission and absorption spectra and selection rules, DeBroglie hypothesis, neutron diffraction, the Schroedinger wave equation, the uncertainty principle, systematics and structure of the nucleus, nuclear forces and nuclear models.

98.562 Radiation Biology (3-0)3 Prerequisite: Introductory nuclear course and course in human physiology. Study of biological effects and mechanisms of action of ionizing radiations from subcellular through whole organism and ecological levels.

98.581 Math Methods in RS&P (3-0)3 Prerequisite: Permission of instructor. A course for those majoring in Radiological Sciences and Protection. An applied course emphasizing the mathematical skills used in radiological sciences/health physics fields including special techniques used in radiation physics, radiation dosimetry, and radiation shielding. Microcomputer applications including numerical techniques will be included.

98.582 Numerical Methods in RS&P (3-0)3 Prerequisite: 98:581 and permission of instructor. Advanced mathematical treatment of topics covered in 98:581 with extensive application of computer techniques to problem solutions applicable to Radiological Sciences and Protection.

98.596 Medical Physics (3-0)3 Prerequisite: Permission of instructor. A discussion of the methods and procedures involving the use of radiation and radioactive materials in medical diagnosis and therapy, including medical radiation dosimetry and computer applications.

98.670/671 Graduate Accelerator Health Physics Internship (0-9)3 Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98.672/673 Graduate Reactor Health Physics Internship (0-9)3 Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98.674/675 Graduate Medical Health Physics Internship (0-9)3 Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98.676/677 Graduate Medical Physics Internship (0-9)3 Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98.678/679 Graduate Health Physics Internship (0-9)3 Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98.680/681 Advanced Accelerator Health Physics Internship (0-9)3 Prerequisite: 98.670/671 and advance approval.

98.682/683 Advanced Reactor Health Physics Internship (0-9)3 Prerequisite: 98.672/673 and advance approval.

98.684/685 Advanced Medical Health Physics Internship (0-9)3 Prerequisite: 98.674/675 and advance approval.

98.686/687 Advanced Medical Physics Internship (0-9)3 Prerequisite: 98.676/677 and advance approval.

98.688/689 Advanced Graduate Health Physics Internship (0-3)1 Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98.690/691 Advanced Graduate Health Physics Internship (0-6)2 Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98.692/693 Advanced Graduate Health Physics Internship (0-9)3 Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98.704/705 Supervised Teaching in Radiological Sciences (0-0)0 All Teaching Assistants are required to register for supervised teaching.

98.711/712 Grad. Seminar in RS&P (1-0)1 Individual presentations by students, faculty, and staff of advanced topics, original research or journal articles.

98.731/732 Advanced Projects in RS&P (0-9)3 An opportunity for individual study under the direction of a staff member of topics related to Radiological Sciences and Protection.

98.733 Graduate Project in Radiological Sciences (0-9)3 Prerequisite: Selection of project option, completion of a minimum of one semester of graduate study in Radiological Sciences and Protection and approval of proposal by faculty advisor. This course provides research credit for a project done by master's degree candidates.

98.743/746/749 M.S. Thesis Research in RS&P (0-9)3,(0-18)6,(0-27)9 Prerequisite: Completion of a minimum of one semester of graduate study in Radiological Sciences and Protection and approval of proposal by thesis committee. This course provides credit for thesis research done by master's degree candidates.

DEPARTMENT OF REGIONAL ECONOMIC AND SOCIAL DEVELOPMENT

Department Chair

John Wooding
B.Sc., Economics and Political Science, M.A., Politics, Cornell University; Ph.D Politics, Brandies University.

Graduate Coordinators

Laurence F. Gross
B.A. English, Wesleyan University; Ph.D., American Civilization, Brown University.

Philip I. Moss
B.A. Economics, Johns Hopkins University; Ph.D Economics, Massachusetts Institute of Technology.

Faculty

Dean Bergeron
B.A. History, St. Michael's College; M.A. Villanova University.

Robert Forrant
M.A. History, Northeastern University; Ph.D., History, University of Massachusetts Amherst.

Sara Kuhn
B.A. Philosophy and Social Relations, Harvard College; Ph.D., Urban Studies and Planning, Massachusetts Institute of Technology.

William H. Lazonick
B.Com. University of Toronto; M.Sc. (Economics) London School of Economics; Ph.D., Economics, Harvard University.

John Douglas MacDougall
B.A. & M.A. Philosophy, Political Economics, Balliol College, Oxford University; Ph.D., Sociology, Harvard University.

Arlene McCormack
B.A. Sociology, Boston University; M.A. Sociology, Boston University; Ph.D Sociology, Boston University.

William Mass
B.G.S. University of Michigan; M.P.H. School of Public Health, Harvard; Ph.D., Economics, Boston College.

Jean L. Pyle
B.A. Economics, Bucknell University; M.A. Economics, University of Michigan; Ph.D Economics, University of Massachusetts.

Linda Silka
M.S. Psychology, Oklahoma State University; M.A. Psychology, University of Kansas; Ph.D., Social Psychology, University of Kansas.

Chris Tilly
B.A. Biochemistry, Massachusetts Institute of Technology; Ph.D., Economics and Urban Studies and Planning, Massachusetts Institute of Technology.

Program Objectives

This program provides training in understanding, analyzing, and intervening in regional economic and social development. By development, we mean strengthening people's ability to meet their varied needs. This includes expanding the capacity to produce, but also includes strengthening the capacity to carry out constructive social activity (such as democratic decision-making)--it is both economic and social. The regions involved can range from a single neighborhood to an entire continent.

The degree program has three main objectives. The first is to provide students with a profound and practical understanding of the dynamics of development processes. Second, the program trains students in research skills that are useful for analyzing and tackling development problems. Third, students learn practitioners' tools for solving such development problems--tools that can be useful in a variety of settings including businesses, government agencies, and nonprofit organizations. The program offers students flexibility in choosing the appropriate mix of research and practitioner skills to meet their needs and interests.

The Master of Arts in Regional Economic and Social Development is designed to serve students from a variety of backgrounds. It attracts recent undergraduates from liberal arts fields such as social sciences (Economics, Sociology, Psychology, Political Science) and History, and also from practice-oriented fields such as Management, Education, and Engineering.

For those already working in public or private sector fields related to economic and social development, it can enhance skills and provide opportunities for career advancement. It is specifically designed to speak to the interests of international students as well as domestic ones. Graduates of the program will be prepared to assume professional roles in local, state, and national government agencies (in the United States and abroad); in research, consulting, and planning aspects of business; and in nonprofit organizations working on economic or social development. Students who choose to do so will also be prepared to go on to doctoral programs in social sciences, history, public policy, planning, and management.

The Master of Arts offers three concentrations: Organization, Technology, and Policy; Regional and Community Development; and Social and Historical Dynamics.

Admissions Requirements

The Regional Economic and Social Development master's program at the University of Massachusetts at Lowell is designed not only for recent college graduates, but also for older, non-traditional, and mid-career students with experience in a variety of work and community settings. The requirements for admission include:

1. Baccalaureate degree from an accredited institution college or university.
2. An undergraduate grade point average of 2.8 or better. Applicants must submit an official transcript from their undergraduate institution.
3. Acceptable scores on the Graduate Record Examination Aptitude Test. (Use of GMAT scores may be approved by the graduate coordinator.) Students for whom English is not a national language must also submit a score for the Test of English as a Foreign Language (TOEFL).
4. Three letters of reference from individuals familiar with the educational and/or professional performance of the applicant.
5. A personal letter including a statement about the applicant's professional interests, educational and work qualifications, and future goals.
6. A curriculum vitae summarizing education and work experience.
7. An interview may be requested by the Graduate Admissions Committee.
8. Proof of residency.

Students may be admitted in one of two categories:

1. Matriculated student. A fully accepted degree candidate who meets all criteria.
2. Matriculated with conditions. From time to time, a student may be accepted conditionally into the program. To become a fully matriculated student, the student must receive at least a 3.0 grade point average in nine credit hours of Regional Economic and Social Development graduate level courses, while also completing any conditions established by the Graduate Admissions Committee. Conditional matriculation requires that students meet conditions 1 and 2 above.

Part-Time and Full-Time Study

MA students may attend either full-time or part-time. Most courses will be scheduled in the evening. Courses will be offered in fall and spring terms, and some courses may be available during the summer. Students taking a full-time load of 12 credits per semester can finish the program in three semesters. Students taking 9 or more credits in a semester will be considered full-time students.

B.A./M.A. and B.S./M.A. Options

Undergraduate majors in related fields at the University of Massachusetts at Lowell may enroll in a B.A./M.A. or B.S./M.A. program that allows students to complete both degrees in five years. Application for this program typically occurs in the Junior year. Additional information is available from the Graduate Coordinators.

Transfer Credit

Matriculated students in Regional Economic and Social Development may transfer up to 9 credits of course work completed at other accredited universities, provided that such courses are within the content area of Regional Economic and Social Development, and do not involve credit for field experience or professional work. Such transfer credit is subject to the approval of the Student Affairs Committee and the Graduate School.

Degree Requirements

A total of 30 academic credits, at least 24 of which must be taken at the University of Massachusetts at Lowell with a grade average of B or better, is required for completion of the degree.

The course of study includes a required 18 credit core:

- Foundations of Comparative Regional Development (3 credits)
- Organizational Dynamics in Regional Development (3 credits)
- Dynamics of Power and Authority, Diversity, and Inequality (3 credits)
- Work, Technology, and Development (3 credits)
- Research Methods in Economic and Social Development (3 credits)
- Thesis/Project Preparation Workshop (3 credits)

The course of study must also include one of the following:

- Master's Thesis (6 credits in a 33-credit program)
  -OR-
- Master's Project (3 credits in a 30-credit program)

The remaining 9 to 12 credits can be satisfied in a wide variety of ways. Students are encouraged to take advantage of concentrations that specify 9 to 12 credits of additional course work in particular areas. However, students are also encouraged to tailor their program to achieve their own learning and career goals, by combining courses, independent study, and practica as appropriate. Up to 6 credits may be taken outside the Department of Regional Economic and Social Development. Non-core course selections must be approved in advance by the student's graduate advisor.

The Certificate program requires four courses (12 credits).

Graduate Advisor

Each newly-matriculated student in the program will be assigned to an advisor from among the faculty of the graduate program. The student will meet with his/her advisor on a regular basis throughout the course of study to discuss course selections, planning for practica, and the development of the thesis or project. In particular, all non-core course selections require prior approval from the graduate advisor. Once a student selects a faculty supervisor for his/her thesis or project, this faculty member takes over as graduate academic advisor.

Thesis or Project

The capstone to the degree program is a thesis or project demonstrating the student's mastery of the field. Typically, the thesis (6 credits) involves a substantial piece of research in economic and social development, whereas the project (3 credits) involves carrying out and documenting a professional problem-solving activity. In some cases, more in-depth problem-solving activities may qualify for thesis status. In each case, the thesis or project requires prior completion of the core courses including Thesis/Project Preparation Workshop, prior approval of the topic by the Graduate Coordinator and a thesis/project supervisor. Thesis or project work is supervised on an ongoing basis by the student's thesis/project supe-supervisor.

Concentrations

Students are encouraged to take advantage of concentrations that combine specified courses to create curricula focused on particular subject areas and professional goals. A brief description of each concentration follows; for more detailed information see the course descriptions under each heading below.

* *Organization, Technology, and Policy*. This concentration focuses on the knowledge and skills needed to understand and manage innovation, technological change, and industrial development. It is designed to train technology managers for business as well as professionals for public policy arenas.

Courses (credits):

- Dynamics of Cooperation and Competition/ Competition, Cooperation, and Learning Organizations (3)
- International Comparisons of Industrial Development (3)

Choice of:

- Design/Control of Manufacturing Systems (3)
- Managing Technology (3)
- Quantitative Foundations (2)
- Methods Module (1)

* *Regional and Community Development*. This concentration provides tools for analyzing and planning economic development at the local or regional level. It prepares people to work in community-based or government agencies involved with economic development, here and abroad.

Courses (credits):

- Public and development finance (3)
- Community-based planning (3)
- Community development research (3)

Choose one from:

- Regional and Local Economic Development
- Development Principles for Developing Countries

* *Social and Historical Dynamics*. This concentration emphasizes analyzing and acting on social aspects of development It offers skills useful to those working in or with community-based organizations and government agencies concerned with social development, as well as providing a springboard for possible doctoral study.

Courses (credits):

- Social Movements and Empowerment (3)

Choose two from:

- Social Movements and Empowerment:

Issues of Gender, Race, and Ethnicity (3)
Work, Technology, and Society, 1790-1920 (3)
Global Economic Restructuring (3)

COURSE DESCRIPTIONS

57.513 Foundations of Comparative Regional Development (3-0)3 This course offers an initial grounding in economic, historical, political, and sociological methodologies and introduces discipline-based and interdisciplinary approaches to regional development. It introduces students to: identifying and assessing structural factors influencing regional development, defining regional development challenges, and generating problem-solving strategies and public policies. The course highlights the relationship between theory and application, and looks at development at the community, national, and international levels. It makes extensive use of case materials on regional development, including a unit on the development of the Massachusetts economy.

57.511 Dynamics of Power and Authority, Diversity and Inequality (3-0)3 Surveys theories of power, authority, participation, and politics. Building on these theories, examines changing social, political, and economic patterns of inequality based on class, race (and related divisions of ethnicity, religion, caste, nationality), and gender. Reviews various approaches to altering these dynamics (business strategy, public policy, community and social movements). Cuts across units of firm, community, region, and nation, along with corresponding governmental institutions, and links theoretical analysis with study of practical problem solving. Instructor-initiated cases drawn from a variety of national experiences.

57.512 Organizational Dynamics in Regional Development. (3-0)3 Presents theory and practice of how to develop organizations capable of learning, innovating, and empowering their participants. Case studies will focus on challenges and opportunities posed to contemporary organizations and institutions engaged in economic development. These cases will be drawn from, and principles will be applicable to, for-profit businesses, public and nonprofit agencies, and voluntary organizations. This course will also examine the nature of interactions among these various types of organizations and institutions within a variety of social and historical settings.

57.514 Work, Technology and Develolpment (3-0)3 Surveys issues of work organization and technological change as they play key roles in the development process. Contrasts different systems of production, and identifies key changes in the work roles and responsibilities of non-supervisory employees, front line supervisors and middle and upper management. This course includes comparisons of historical transformations at key moments in the emergence of internationally competitive developed economies. In addition, selected contemporary cases exemplify current issues in the ongoing transformation of work organization and technology. Introduces students to practical considerations in work process design. Includes required student projects.

57.711 Research Methods in Economic and Social Development (3-0)3 An applied survey of research methods appropriate for regional economic and social development. Students will learn data presentation and basic descriptive statistics, as well as basics of researching data sources and primary data-gathering techniques (survey, case study, archival), and a framework for deciding when particular methods of data-gathering and analysis are appropriate. Students will apply the techniques as they learn them.

57.712 Thesis/Project/Practicum Preparation Workshop (3-0)3 This workshop prepares students to undertake a thesis, practicum or project. Working with the professor, each student identifies a feasible research question or project/practicum, identifies data sources and methods, conducts a literature review, chooses an advisor, and writes and revises a thesis proposal or project/practicum proposal. Prerequisites: Foundations; Dynamics of Power and Authority; Work, Technology and Development; Organizational Dynamics; Research Methods.

57.521 Competition, Cooperation, and Development (3-0)3 Global perspectives drive this examination of competitive advantage as reflected, first and foremost in manufacturing organizations at the aggregate economy, industry, company, and production unit levels. The relationships between private and public policies at both the national and regional levels that affect economic development will be examined. Student projects and practica will utilize concepts presented in this course on the theory of the innovative firm, organizational integration and network economies, financial commitment and strategic decisions, and sustainable development.

57.523 Technology, Strategy, and Innovation (3-0)3 This course explores the relationships among science, technology, organizational strategy and innovation. Organizational capabilities are examined from a knowledge-building point of view along four dimensions: employee knowledge and skills, physical technical systems, managerial systems, and the values and norms determining the kinds of knowledge that are sought and nurtured. When and how can science and technology leadership be developed, and when and how can it generate superior performance for firms, industries and regions? When and how will current structures and operations impede or advance effective responses to new opportunities and changed external conditions and how can successful organizational change be introduced? While this course is focused on private and public sector strategy formulation, it is intensely concerned with implementation. The interdependence of macro strategic decisions and micro operational implementation will be investigated at the level of the factory or office floor, the interactions across functional units within an organization, and in relations with other firms, agencies, universities, suppliers and customers. Frameworks and tools for evaluating the proper role for basic research, technology choices, new product and project development process, and the development of human resource capabilities will be introduced.

57.599 Inequality, Organization, and Development (3-0)3 Despite the lowest unemployment rate in 25 years, the economic recovery of the 1990s has brought a "Treadmill Economy" – running faster with minimal gain. With low productivity growth, surprisingly little growth in wages and a long-term slowdown in economic growth since the 1970s, the United States continues to experience increasing inequality. What forces are at work shaping these trends and can they be modified or reversed on the local, state and regional levels? How have these trends both shaped and been influenced by social and business policies concerning poverty and welfare, local and urban development, technology and economic development, changes in work organization and labor-management relations, domestic investment and international competition? This seminar course will bring local and national experts on these issues to present their findings and discuss their view of future prospects for local and regional social and economic development policy.

57.545 Gender Differences At Work (3-0)3 This course explores the dimensions of women's and men's work in both the paid and unpaid labor force, including the household. Issues will include occupations, earnings, career ladders, health safety and responses to inequalities. The importance of class, ethnic/racial, and native-born versus immigrant status is fully integrated throughout the course. This course is designed to be relevant for both graduate students and upper-level undergraduates in a variety of disciplines.

57.590 Software Design In Context (3-0)3 A graduate level introduction to selected social, organizational, ethical, and policy perspectives on information technology. Through reading and discussion of both theoretical and applied material on software development and computerization, students will gain an interdisciplinary exposure to the context of computer technology.

57.533 Where are jobs? Regional And Local Economic Development (3-0)3

This course builds on the material taught in Foundations of Comparative Regional Development and provides students with further analytic training in regional analysis tools, more detailed case study analysis, more field work on economic development issues, and more training in evaluating and developing public policy strategies for sustainable regional and local economic development. While focusing on New England and the Merrimack Valley, this course will involve comparative study of other regions in the United States and in other advanced industrialized countries.

57.715 Community Development Research (3-0)3 Builds on Research Methods to provide training in research techniques appropriate for community development. Focuses on data collection techniques useful in communities that are too small and/or poorly documented to draw on standard large data sets. Techniques reviewed include use of administrative data, survey design and administration, focus groups, and ethnography. Course includes small student research projects.

57.535 Community Based Planning (3-0)3 Develops theory and practice of participatory planning for development, particularly at the community level. Covers the basic steps of planning, including goal setting, prioritization, strategy development, and implementation. Considers public sector, nonprofit and private sector roles in planning. Includes case studies from a diverse set of communities, including some international examples.

57.525 Finance In Industrial Development (3-0)3 Economic development is the process that enables a society to generate higher material standards of living. It requires investments in productive resources that are developed and utilized in particular enterprises, communities, and regions. The need to finance these investments means that productive resources must be mobilized now and on a continuing basis if returns are to be generated in the future. This course is about the ways that governments and businesses of different nations have financed the process of economic development. The course will begin with the basic historical facts of the economic development of nations in the twentieth century, and then will consider the existing theories of economic development that have been put forward to explain these facts. We will then proceed to a consideration of the finance of economic development in the historical evolution of a number a today's advanced economies, including the United States, Japan, and Germany. Next we will look more closely at the particular roles and methods of governments (federal, state, and local) and enterprises (new ventures and going concerns) in financing economic development. The course will focus comparatively on problems of financing economic development in the United States and Japan, with particular emphases on the financial behavior of large corporations, the financial requirements of small and medium-sized enterprises, the financial needs of an aging population, and the politics of public finance. Finally, we will apply the mode of analysis that we develop in the course to explaining the recent Asian financial crisis and its implications for the United States.

57.543 Social Movements and Enpowerment (3-0)3 This course focuses on ways in which non-elite groups and individuals can gain control over important aspects of economic and social development. These aspects include decisions about such matters as industrial location, work conditions, community services and environmental protection; and the status of women, ethnic/racial minorities and other disadvantaged groups. Special attention is paid to the dynamics and potential impact of grass-roots social movements.

57.537 Development Principles For Developing Economies (3-0)3 This course explores alternative visions of what is meant by `development,' what is involved in the development process, and who benefits from it. A country must choose the goals (such as growth, equity, or sustainable human development) it hopes to achieve and develop a strategy for attaining them. It must make critical decisions regarding the roles of major sectors of the economy (agriculture, industry, services, the extent of foreign involvement), the form of organization they will have (large or small scale, centralized or decentralized, private or public ownership), and the roles of major institutions (government, financial sectors, multinational corporations, and international aid agencies). The theoretical and practical issues we will discuss have broad relevance for understanding the varied development process in Asian countries, the struggles of middle-level developing countries (such as Mexico or Brazil) or the despair of the broad group of countries for which development seems an increasingly dimmer vision (many African countries). The course emphasizes interconnections in the world economy. On the one hand, policies shaped by institutions in First World or industrialized countries have a significant and often adverse impact on developing countries. On the other hand, the failure of development programs in many countries thought to be `developing' has a critical impact on the future of industrialized nations. Students will be expected to develop thoughtful positions on current controversial issues in development and to suggest appropriate strategies for change.

A. Politics and Economics Of Public Policy (3-0)3 The course will provide students with both a set of analytical frameworks to understand how and why specific public policies develop, and a set of normative perspectives to assess what makes for "good" public policy. Our treatment will be interdisciplinary drawing from areas of economics and political science. Following some grounding in the political economy of the role of government and policy making in a market based economy such as the United States, we will do case studies to understand and to evaluate policies from a variety of current areas of interest to the students and professors.

GRADUATE SCHOOL OF EDUCATION

Dean

Donald E. Pierson
Professor; A.B., Princeton University; Ed.M., Ph.D., Harvard University.

Chairperson

William T. Phelan
Professor; A.B., Boston College; A.M., Catholic University; Ph.D., University of Chicago.

Department Coordinators

Anita M. Greenwood
Associate Professor; B.Sc., P.G.C.E., Birmingham University, U.K.; M.Ed., Ed.D., University of Massachusetts Lowell.

Brenda L. Jochums Slez
Professor; B.S., University of Illinois; M.A., Bradley University; Ph.D., Indiana University.

Faculty

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Norman F. Benson
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Assistant Professor and Director, Tsongas Center for Industrial History; B.A. Hamilton College; M.A., Harvard University; Ph.D., Connecticut University.

Regina M. Panasuk
Assistant Professor; B.S., Leningrad Institute of Electrical Engineering, Leningrad, Russia; M.S., Leningrad Instiute of Methods and technologies of the Academy of Pedagogical Sciences.

Juan C. Rodriguez
Professor; B.A., Ed.M., Catholic University, Lima,Peru; Ed.D., University of Massachusetts Amherst.

Emeritae:

M.Virginia Biggy
Professor and Dean Emerita; B.S., Ed.M., Ed.M., Ed.D., Boston University.

Penelope Z. Demogenes
Associate Professor Emerita; B.S., University of Lowell; Ed.M., C.A.G.S., Boston University

Alice G. Kiernan
Associate Professor Emerita; B.S., University of Lowell; Ed.M., Boston University.

Mary E. McGauvran
Professor Emerita; B.S., University of Lowell; Ed.M., Ed.D., Boston University.

Anne M. McParland
Associate Professor Emerita; B.S., University of Lowell; C.A.S., Harvard University; Ed.D., Boston University.

The Graduate School of Education offers graduate degree programs which provide professional preparation for those who aspire to serve in the roles of teacher, curriculum specialist or director, school principal, higher education administrator, college faculty, policy planning, consultant, and other positions of educational leadership.

DEGREE PROGRAMS

The Master of Education degree is offered in: Curriculum and Instruction (with two options: Graduate Program in Teaching, and English as a Second Language); Educational Administration; and Reading and Language.

The Certificate of Advanced Graduate Study is offered in: Curriculum and Instruction; Administration, Planning and Policy; and Reading and Language.

The Doctor of Education Degree is offered in: Mathematics and Science Education; Leadership in Schooling; and Language Arts and Literacy.

ADMISSION TO DEGREE PROGRAMS IN EDUCATION

Application:

In addition to the requirements for admission listed in this catalogue, applicants must file the following documents with the Graduate School:

1. A completed application form, available from the Graduate School Office.

2. Official transcripts from each undergraduate and graduate school previously attended. These official transcripts must be sent directly to the Graduate School by the colleges which the applicant attended. Transcripts sent by the applicant and copies of transcripts cannot be accepted.

3. An official copy of the applicant's scores obtained on the Graduate Record Examination must be mailed directly to the Graduate School Office.

4. A two-page statement of purpose in which the candidate describes his/her experience and reasons for entering a graduate level program.

5. Letters of recommendation from three persons who are qualified to evaluate the applicant's academic and professional abilities. The forms for these recommendations are contained in the admission packet.

Upon receipt, the Graduate School will forward the above documents to the Graduate School of Education. All decisions on admissions are made by the Admissions and Standards Committee of the Graduate School of Education and forwarded to the Graduate School for final action. Applicants approved for admission to all graduate programs in the Graduate School of Education must meet general education prerequisites consistent with the standards of the National Council for Accreditation of Teacher Education. Applicants who are accepted for admission will be informed of any general education deficiencies by letter from the Graduate School of Education.

Transfer Credit M.Ed., C.A.G.S., and Ed.D. Programs

The Graduate School of Education follows the Graduate School requirements regarding the transfer of credit (see front of catalogue) with the following clarifications: no more than nine (9) credits for the Graduate Program in Teaching, no more than twelve (12) credits for other Masters degrees, nine (9) credits for C.A.G.S. or twenty four (24) credits for Doctoral programs may be transferred from other accredited institutions of higher education. Only courses with grades of B or better, completed within five years of matriculation, may be transferred.

Graduate Advisor

A student who accepts admission will be assigned to a faculty advisor in the Graduate School of Education. The advisor's responsibility is to: 1) provide academic counseling to the student relative to the program of study and 2) periodically evaluate the student's academic progress, making recommendations as necessary to the Admissions and Standards Committee concerning the student's continuation, dismissal, or qualifications for a degree.

Degree Requirements

Each graduate student is personally responsible for complying with all rules and regulations of the Graduate School and the Graduate School of Education, and for fulfilling all degree requirements.

MASTER OF EDUCATION (M.Ed.)

1. To qualify for admission to a graduate degree program at the Master of Education level, an applicant must have completed a baccalaureate degree program with a scholastic record that gives evidence of ability to succeed in graduate work.

2. In order to qualify for a Master of Education degree, each candidate must meet the following requirements:

3. Complete a minimum of thirty (30) credits of required course work in a specific degree program.

4. Complete all course requirements for the degree program at this University. A maximum nine (9) credits for the Graduate Program in Teaching and twelve (12) credits for other Masters degrees taken at another accredited institution is the only exception granted.

5. Complete satisfactorily the specified internship and/or field practicum, and appropriate seminar, under supervision of a designated faculty member in the Graduate School of Education.

6. Complete all course requirements for the degree with a cumulative grade-point average of B or better.

7. Complete the degree within five years of the date of admission.

A. Curriculum and Instruction (M.Ed.)

Designed for certified teachers who will provide instructional leadership in the role of supervisor, department chairperson, or curriculum specialist. The core of the Master of Education degree consists of distribution requirements in the following areas: Foundations of Education, Research and Evaluation, Specialization, and Practicum. Course offerings which apply to each area are listed below. A minimum of thirty (30) credits is required for the Master of Education in Curriculum and Instruction degree.

Foundations of Education (minimum 6 credits)

Two 01 courses should be selected with the advice and approval of the faculty advisor.

Research and Evaluation (minimum 3 credits)

One course should be selected

07.540 Research Methods for Practitioners
07.640 Research Methods
07.642 Program Evaluation

Specialization (minimum 9 credits)

04.636 Theory and Research in Curriculum
04.638 Curriculum Design K-12
05.639 Planning Process

Electives (minimum 9 credits)

Three courses may be selected with the advice and approval of a faculty advisor.

Practicum (minimum 3 credits)

04.649 Practicum/Seminar for certification as Supervisor/Director
04.650 Practicum/Seminar in Curriculum and Instruction (non-certification)

CIT

Curriculum and Instruction (M.Ed.)
Option 1: The Graduate Program in Teaching

Designed for individuals who seek initial certification. The program includes provisional certification with advanced standing in the Commonwealth of Massachusetts.

Certification opportunities are available in the following areas: Elementary Education, High School or Middle School English, Mathematics, History, Social Studies, Biology, Chemistry, Earth Science, Physics, Music Education, and Health Education. Additionally, Elementary Education candidates may be eligible to seek certification in early childhood or as a middle school generalist.

Requirements

Successful applicants for the elementary program must have an undergraduate major or a minimum of 24 credits in an arts or science academic content area. In addition, the applicant must meet prerequisite requirements in mathematics, science, history, English, art or music, and health.

Applicants for the secondary program must have a degree or equivalent in the content area they wish to teach.

Applicants are expected to achieve a minimum grade point average of 3.0 in undergraduate work. Satisfactory scores on the Graduate Record Exam are also required. All candidates must pass the Communication and Literacy Test and a Subject Test of the Massachusetts Educator Certification Tests to qualify for Massachusetts certification.

Elementary Education (1-6)

Foundations of Education (minimum 6 credits)

01.501 Diversity in the Classroom
01.502 Child Development and Assessment of Learning: Elementary

Specialization: Elementary Teaching Methods (minimum 15 credits)

02.556 Reading and Reading Disabilities
02.551 Mathematics Education
02.552 Social Studies Education
02.553 Language Arts and Literacy Education
02.563 Science Education

Practicum (minimum 9 credits)

In order to proceed to the practicum, the candidate must have a grade point average of 3.25 or better, and pass the Communication and Literacy portion of the Massachusetts Educator Certification test.

02.578 Practicum and Analysis of Teaching Seminar:Elementary

Elementary/Early Childhood (1-6)(preK-3)

Foundations of Education (minimum 6 credits)

01.501 Diversity in theClassroom
01.502 Child Development and Assessment of Learning: Elementary

Specialization: Elementary Teaching Methods (minimum 18 credits)

02.556 Reading and Reading Disabilities
02.551 Mathematics Education
02.552 Social Studies Education
02.553 Language Arts and Literacy Education
02.563 Science Education
One Early Childhood Course

Practicum (minimum 15 credits)

In order to proceed to the practicum, the candidate must have a grade point average of 3.25 or better, and pass the Communication and Literacy portion of the Massachusetts Educator Certification test.

02.578 Practicum and Analysis of Teaching Seminar: Elementary
02.598 Practicum: Early Childhood

Elementary/Middle School (1-6)(5-9): Classroom Generalist

Foundations of Education (minimum 6 credits)

01.501 Diversity in the Classroom
01.502 Child Development and Assessment of Learning:Elementary

Specialization: Elementary Teaching Methods (minimum 18 credits)

02.556 Reading and Reading Disabilities
02.551 Mathematics Education
02.552 Social Studies Education
02.553 Language Arts and Literacy Education
02.563 Science Education
One Middle School Course

Practicum (minimum 15 credits)

In order to proceed to the practicum, the candidate must have a grade point average of 3.25 or better, and pass the Communication and Literacy portion of the Massachusetts Educator Certification test.

02.578 Practicum and Analysis of Teaching Seminar: Elementary
02.597 Practicum: Middle School

High School (9-12): Subject Specialist

Foundations of Education (minimum 9 credits)

01.501 Diversity in the Classroom
01.502 Child Development and Assessment of Learning: Secondary
One other foundations course with the approval of a faculty advisor.

Specialization (minimum 12 credits)

One graduate course in field of certification
02.xxx Curriculum and Teaching in Major Area
02.580 Interdisciplinary Methods
One elective with the approval of a faculty advisor.

Practicum (minimum 9 credits)

In order to proceed to the practicum, the candidate must have a grade point average of 3.25 or better, and pass the Communication and Literacy portion of the Massachusetts Educator Certification test.

02.xxx Practicum and Analysis of Teaching Seminar:Secondary

High School/Middle School (9-12)(5-9): Subject Specialist

Foundations of Education (minimum 9 credits)

01.501 Diversity in the Classroom
01.502 Child Development and Assessment of Learning: Secondary
One other foundations course with the approval of a faculty advisor.

Specialization (minimum 12 credits)

One Middle School Course
02.xxx Curriculum and Teaching in Major Area
02.580 Interdisciplinary Methods
One elective with the approval

of a faculty advisor.

Practicum (minimum 15 credits)

In order to proceed to the practicum, the candidate must have a grade point average of 3.25 or better.

02.xxx Practicum and Analysis of Teaching Seminar:Secondary
02.597 Practicum: Middle School

Middle School (5-9): Subject Specialist

The requirements are identical to those for the combined high and middle school certification, but only ONE practicum (middle school) is required.

CURRICULUM AND INSTRUCTION (M.ED.) Option 2

English as a Second Language

Designed for teachers who hold a first certification and seek an additional certificate as an English as a Second Language Teacher.

Prerequisites

For certification as an ESL teacher, the Massachusetts Department of Education requires: six course credits in American Literature, six course credits in English Literature and passing an English language proficiency examination.

Foundations of Education (minimum 9 credits)

02.502 Sociocultural Perspectives of Teaching ESL
02.514 Education of Linguistically and Culturally Diverse Students
02.517 Community Organization and Parental Participation

Certain courses may be substituted for required foundations courses with the advice and written approval of a faculty advisor.

Research and Evaluation (minimum 3 credits)

One course should be selected
02.508 Approaches to Second Language Testing and Assessment

Specialization (minimum 15 credits)

02.501 First and Second Language Acquisition
02.503 Methods of Second Language Instruction
02.504 Curriculum and Adaptation in Teaching ESL
02.505 Language Arts Instruction for ESL Teachers
02.509 The Bilingual Child with Special Needs

Electives (1 course: minimum 3 credits)

Certain courses may be substituted for required specialization courses with the advice and written approval of a faculty advisor.

Practicum (minimum 6 credits)

02.515 ESL Practicum and Seminar (for those seeking ESL certification)

B. Educational Administration (M.Ed.)

The master's degree program in Educational Administration is designed to meet the needs of those planning careers as practitioners in a variety of middle-level administrative areas in public and private educational institutions as well as community organizations and various human service agencies. The program also serves as the initial sequence of study for those planning further graduate study in administration in preparation for senior positions as administrators, planners, researchers, or theorists.

Professional Experience

Each candidate for the degree in Educational Administration is required to complete at least three years full time employment in an educational institution or a human service agency prior to completion of degree requirements.

Students seeking certification as Principal must be certain that all courses required for certification are completed.

Foundations of Education (minimum 6 credits)

Two 01 courses should be selected with the advice and approval of the faculty advisor.

Research and Evaluation (minimum 3 credits)

One course should be selected
07.540 Research Methods for Practitioners
07.640 Research Methods
07.642 Program Evaluation

Specialization in Administration, Planning, and Policy (minimum 12 credits)

05.620 Introduction to Educational and Human Service Administration
05.639 Planning Process
05.640 Analysis of Educational and Human Service Organizations
05.642 Principles of Supervision (or 05.643)
05.643 Principalship (or 05.642)

Electives (minimum 6 credits)

To be selected with the advice and approval of the faculty advisor.

Practicum (minimum 3 credits)

05.644 Educational Administration (non-certification)
05.646 School Principal N-6
05.647 School Principal 5-9
05.648 School Principal 9-12

C. Reading and Language (M.Ed.)

Designed for candidates who hold a teaching certificate in either elementary or secondary English education. The degree program requires thirty (30) credits of course work including six (6) credits in Practicum. The program prepares consultant teachers of reading and language curriculum supervisors. Students seeking certification as Consulting Teacher of Reading must be certain that all courses for certification are completed.

Prerequisites

Certification as an elementary or secondary English teacher. One undergraduate or graduate course concerning Developmental Reading Elementary and Developmental Reading Secondary. These prerequisite courses do not count toward the thirty (30) credits required for the Master of Education in Reading and Language degree.

Foundations of Education (minimum 3 credits)

One course should be selected
01.610 Theories of Learning
01.611 Cognition and Instruction

Research and Evaluation (minimum 3 credits)

One course should be selected
07.540 Research Methods for Practitioners
07.640 Research Methods
07.642 Program Evaluation

Specialization in Reading and Language (minimum 15 credits)

02.501 First and Second Language Acquisition
06.528 Clinical Assessment of Reading and Language Disabilities
06.530 Young Adult Literature
06.531 Organization and Supervision of Reading and Language Programs
06.549 Seminar in Reading and Language

Electives (minimum 3 credits)

To be selected with the advice and approval of a faculty advisor

Practicum (minimum 6 credits)

06.548 Practicum in Reading and Language

CERTIFICATE OF ADVANCED GRADUATE STUDY (C.A.G.S.)

To qualify for admission to a graduate program at the Certification of Advanced Graduate Study level, an applicant must have a master's degree from an accredited college or university with a cumulative grade point average of not less than 3.0. Additionally, each candidate must meet the following requirements:

1. Complete a minimum of thirty credits of course work in the specified certificate program.

2. Complete all course requirements for the certificate program at this university. A maximum of 9 credits of course work transferred from another accredited institution is the only exception granted.

3. Complete all course requirements with a cumulative grade point average of B or better. No additional course credits may be permitted in order to achieve the grade point average of B or better required for the certificate.

4. Pass an area comprehensive examination.

5. Satisfactorily complete a Qualifying Paper as approved by his or her faculty committee.

6. Complete the program within five years of the date of admission.

7. It is expected that an approved outline for a Qualifying Paper will be completed during the Research Seminar and the completed paper submitted at least two weeks prior to the clearance date of the year that the student anticipates graduation.

8. Students must demonstrate competency in knowledge of research methods and computer literacy. This may be achieved by courses listed on transcripts, examinations or by other means approved by the student's advisor. Those students unable to fulfill this area by the stated means should take a course or courses to develop these competencies. Courses taken will not accrue to C.A.G.S. credit.

Note: Students seeking Massachusetts certification as Supervisor/Director, Principal, or Consulting Teacher of Reading must also fulfill a special set of courses and practica. Students should consult with their advisors before beginning course work.

A. Curriculum and Instruction (C.A.G.S.)

Foundations (mininum 3 credits)

04.670 Issues in Curriculum and Instruction

Research and Evaluation (minimum 6 credits)

04.671 Research Seminar I in Curriculum and Instruction

04.672 Research Seminar II in Curriculum and Instruction

Specialization (minimum 12 credits)

04.636 Theory and Research in Curriculum and Instruction

04.638 Curriculum Design K-12

05.639 Planning Process

04.642 Politics of Curriculum Change

Electives (minimum 9 credits)

Three electives should be selected with the advice and approval of the student's advisor.

Students must pass a comprehensive examination in the area of Curriculum and Instruction.

Those who have completed C.A.G.S. specialization courses as part of their master's degree program may meet the C.A.G.S. credit requirements by selecting other courses with the advice and approval of their advisor.

B. Administration, Planning, and Policy (C.A.G.S.)

Research and Evaluation (minimum 6 credits)

05.670 Research Seminar I in Administration, Planning, and Policy

05.671 Research Seminar II in Administration, Planning, and Policy

Specialization in Administration, Planning, and Policy (minimum 12 credits)

05.620 Introduction to Educational and Human Service Administration

05.639 Planning Process

05.640 Analysis of Educational and Human Service Organizations

05.642 Principles of Supervision or

05.643 Principalship

Electives (minimum 12 credits)

These courses should be selected with the advice and approval of the faculty advisor.

Students must pass a comprehensive examination in the area of Administration, Planning, and Policy.

C. Reading and Language (C.A.G.S.)

Foundations (minimum 3 credits)

06.670 Issues in Reading and Language Instruction

Research and Evaluation (minimum 6 credits)

06.671 Research Seminar I in Reading and Language

06.672 Research Seminar II in Reading and Language

Specialization in Reading and Language (minimum 12 credits)

In consultation with the advisor, the student will select 12 credits of course work in the 06. area.

Electives (minimum 9 credits)

Three courses should be selected with the advice and approval of the faculty advisor.

Students who have completed core courses in the master's degree program may waive certain core requirements of the C.A.G.S. program. Courses should be selected with the advice and approval of the student's advisor.

Students must pass a comprehensive examination in the area of Reading and Language.

DOCTOR OF EDUCATION (Ed.D.)

To qualify for admission to a graduate program at the Doctor of Education level, an applicant must have earned a baccalaureate degree from an accredited college as well as a master's degree appropriate to the intended field of specialization from an accredited college. A cumulative grade point average of no less than 3.0 is expected. A personal interview with the Graduate Coordinator, the Dean and/or the Academic Standards and Admissions Committee may also be required.

Degree Requirements

1. Complete a minimum of sixty (60) credits in the specified doctoral program, of which a minimum of nine (9) credits must be dissertation research. A maximum of six (6) credits of Advanced Research Seminar work may be counted toward dissertation research. Students may request for transfer a maximum of twenty four (24) credits of course work taken prior to matriculation at another accredited institution toward the doctoral degree.

2. Complete the stipulated course requirements for the degree program at this university.

3. Complete all course requirements for the degree with a cumulative grade point average of B or better.

4. Complete the residency requirement.

5. Satisfy the Computer Literacy

requirement.

6. Pass two (2) doctoral examinations.

7. Satisfactorily complete and defend a dissertation as approved by the candidate's dissertation committee.

8. Complete the program within seven years from the date of admission.

Note: Students seeking Massachusetts certification as Supervisor/Director, Principal, or Consulting Teacher of Reading must fulfill a separate set of courses and practica. Students should consult with their advisors before beginning course work.

Core courses in doctoral programs are open only to students who are matriculated into a doctoral program, or with the specific permission of the instructor.

A. Mathematics and Science Education Doctoral Program (Ed.D.)

Foundations of Education (minimum 6 credits)

01.645 Perspectives and Visions of Schooling: I
01.646 Perspectives and Visions of Schooling: II

Research and Evaluation (minimum 9 credits)

07.701 Seminar in Data Analysis
07.702 Seminar in Research Methodology and Design
07.xxx An additional course approved by the faculty advisor.

Field of Specialization Requirements

1. Integration Requirements (minimum 9 credits)

04.622 Mathematics, Science, and the Educated Mind
04.614 Constructivist Perspectives in Mathematics and Science Education
04.617 Advances in Mathematics, Science and Technology Education

2. Concentration Requirements (minimum 15 credits)

04.626 Development of Concepts in Science (or 04.627)
04.627 Development of Concepts in Mathematics (or 04.626)
04.628 Reasoning and Problem Solving in Science (or 04.629)
04.629 Reasoning and Problem Solving in Mathematics (or 04.628)

Three additional 03 or 04 courses selected with the approval of the faculty advisor.

Electives (minimum 12 credits)

Four courses selected with the approval of the faculty advisor.

If the candidate does not hold a master's degree in Science, Mathematics or Engineering, then 6 credits must be in collateral fields outside Education

Dissertation Research (minimum 9 credits)

B. Leadership In Schooling Doctoral Program (Ed.D.)

Foundations of Education (minimum 6 credits)

01.645 Perspectives and Visions of Schooling I
01.646 Perspectives and Visions of Schooling: II

Research and Evaluation (minimum 9 credits)

07.701 Seminar in Data Analysis
07.702 Seminar in Research Methodology and Design
07.xxx An additional course approved by advisor

Field of Specialization Requirements (minimum 9 credits)

01.636 Sociology of Educational Communities
05.650 Instructional Leadership and School Reform
05.652 Managing Change and Conflict in Schools

Electives (27 credits)

Twenty-seven semester hours will be selected, by the student with the advice and approval of the faculty advisor, to provide appropriate specialization in a professional field.

Dissertation Research (minimum 9 credits)

C. Language Arts and Literacy Education Doctoral Program (Ed.D.)

Foundations of Education (minimum 6 credits)

01.645 Perspectives and Visions of Schooling: I
01.646 Perspectives and Visions of Schooling: II

Research and Evaluation (minimum 9 credits)

07.701 Seminar in Data Analysis
07.702 Seminar in Research Methodology and Design
07.xxx An additional course approved by advisor.

Field of Specialization Requirements (minimum 9 credits)

06.670 Issues in Reading and Language Instruction
06.673 Curriculum Design and Instruction for English/Language Arts
06.674 Curriculum Design and Instruction for English/Language Arts

Electives (27 credits)

Twenty-seven semester hours will be selected by the student, with the advice and approval of the faculty advisor, to provide appropriate specialization in a professional field.

Dissertation Research (minimum 9 credits)

COURSE DESCRIPTIONS

01.564 History of American Education (3-0)3 An analysis of the development of educational thought and practice in the United States within the context of American social, cultural, economic, and intellectual history.

01.610 Theories of Learning (3-0)3 This course offers a detailed analysis of the major contemporary learning theories, both behavioral and cognitive.

01.611 Cognition and Instruction (3-0)3 This seminar relates the fields of cognitive psychology and instructional psychology. The focus is on improving classroom practice by application of cognitive processes.

01.615 Issues in the Philosophy of Education (3-0)3 Topics of contemporary concern will be examined with a view to their philosophical basis. Where applicable, views of the great philosophers will be examined relative to these topics.

01.616 Issues in Sociology of Education (3-0)3 This course conducts an analysis of the topics and conflicts associated with a national commitment to both academic excellence and educational equity.

01.617 Contemporary Issues in Education (3-0)3 This course is concerned with philosophical disputes which have a direct relationship to the problems of education.

01.625 Organization of Schools and School Systems (3-0)3 This course is designed to help students understand the organizational dynamics of schools. The knowledge gained should assist students in identifying and suggesting alternatives to programmatic and behavioral regularities found in a school or human service organization.

01.636 Sociology of Educational Communities (3-0)3 Examines the social, cultural, and political forces that shape the school environment and provide context for teaching and learning. Additionally, the types of existing and desired relationships among schools, families, and communities will be discussed.

01.641 Work, Technology, and Schooling (3-0)3 An examination of the ways in which various ideas of work discipline the goals of

school, the methods of instruction and administrative structure.

01.645/646 Perspectives and Visions of Schooling: I/II (3-0)3/(3-0)3 Open to matriculated doctoral candidates only. Provides students a common reference for considering and understanding significant issues in education. Major concerns in schooling will be examined with a view to historical, sociological, and economic antecedents and implications for the future of education.

01.701 Human Memory and Cognition (3-0)3 This course will cover the fundamentals of human memory and cognition. In addition to modern memory theory, the basic cognitive processes of perception, comprehension, believing, dreaming, imagination, and thinking will be explored.

01.702 Cognitive Psychology: Information Processing Theories of Human Performance (3-0)3 This course will take an in-depth examination of information processing theories of learning and human performance. The functions of schemata and information and memory structures will be analyzed with respect to thinking, imagination, and problem solving.

02.500 Contemporary American Culture (3-0)3 Different aspects of American culture will be explored, from its origin to the twentieth century.

02.501 First and Second Language Acquisition (3-0)3 A study of the general schools of thought that have formed the basis of teaching English as a Second Language. This course is designed to assist students in conceptualizing the foundations of first and second language acquisition.

02.502 Sociocultural Perspectives of Teaching English as a Second Language (3-0)3 Theories of learning in bilingual education and ESL will be presented. The rationale underlying bilingual and ESL education will be discussed. Policies and practices at state and federal levels will be examined.

02.503 Methods of Second Language Instruction (ESL) (3-0)3 Different approaches and teaching procedures in Second Language Instruction will be discussed as well as the methodological models of English as a Second Language instruction.

02.504 Curriculum Materials and Adaptation (ESL) (3-0)3 Curriculum designs and instructional materials used in English as a Second Language will be examined.

02.505 Language Arts Instruction for ESL teachers (3-0)3
Current approaches, methods and techniques for teaching Language Arts and their application to English as a Second Language classrooms.

02.508 Approaches to Second Language Testing Assessment (3-0)3
Procedures to test and assess ESL-Bilingual students.

02.509 The Bilingual Child with Special Needs (3-0)3 Development of awareness, knowledge and skills for teaching culturally and/or linguistically different students who have moderate special needs.

02.512 Linguistics for ESL Teachers (3-0)3
Discusses the contribution of general linguistics theory and research to bilingualism and second language acquisition.

02.514 Education of Linguistically and Culturally Diverse Students (3-0)3
Provides awareness and knowledge to educators of English Language Learners (ELL) on issues involving linguistic and cultural diversity.

02.515 ESL Practicum and Seminar (6-0)6
For ESL Certification. On-site field experience in an ESL classroom, under the supervision of a qualified ESL teachers and faculty of the College of Education.

02.517 Community Organization and Parental Participation (3-0)3 The aim is to prepare school personnel to work effectively with community groups and bilingual parent organizations.

02.525 Bilingual Field Work/Internship (3-0)3 For NON-certification On site field experience in bilingual classroom, under a qualified bilingual teacher and university supervisor.

02.551 Mathematics Education (3-0)3
New approaches in the curriculum and teaching of mathematics in the elementary school; analysis and use of current materials, national and state standards, multimedia approaches, and inductive and problem-solving techniques.

02.553 Language Arts and Literacy Education (3-0)3 Approaches in the teaching and assessment of the language arts in the elementary school will be analyzed. Assorted genres of literature and the development of literature programs for children in multi-cultural environments will be studied.

02.554 Analysis of Teaching (3-0)3
Examines the *Principles of Effective Teaching* and considers how theses principles can be incorporated into successful classroom practice. Focus on Issues of curriculum planning and instruction, teaching and learning strategies, classroom management, equity, state and federal mandates, reflective practice, and professionalism.

02.556 Reading and Reading Disabilities (3-0)3 A critical analysis of fundamental issues and principles in the teaching of reading, including all phases of the elementary reading program. Analysis and remediation of reading disabilities which explores the use of critical diagnostic tools.

02.560 Curriculum Development: Middle/Secondary (3-0)3 Analysis, comparison, and evaluation of a variety of models for curriculum development; evaluation of present curricula in middle and secondary schools, and development of strategies for implementing curriculum reform.

02.562 Social Studies Education (3-0)3
Examines teaching strategies and materials appropriate for the teaching of K-8 social studies. Examines national and state standards for the discipline.

02.563 Science Education (3-0)3
Models the teaching of science as guided discovery while exploring developmentally appropriate concepts in science. Examines national and state standards as well as nationally developed curriculum kit-based materials.

02. xxx Curriculum and Teaching - Major Area: Secondary 7-12 (3-0)3 An analysis of the content, methods, materials, and management techniques used in each major area of the secondary school. Examination of national and state standards for the discipline. The course will include micro-teaching and self-evaluation, as well as school-based observation and participation in secondary schools.

02.xxx. Practicum and Analysis of Teaching
(9-0)9 Prerequisites: All courses and prerequisite courses must be complete. Grade point average must be 3.25 or better.
Full time practicum in the public elementary, middle or secondary schools under the supervision of qualified teachers, principals, and faculty of the College of Education. Weekly seminar and portfolio development addressing the standards for professional teacher certification.

02.580 Interdisciplinary Curriculum Development. (3-0)3 An in-depth analysis of the rationale for developing interdisciplinary and integrated curricula in secondary schools. Students will explore curriculum materials in use and develop an interdisciplinary curriculum of their own.

02.597 Teaching Middle School (6-0)6
Prerequisites: All courses required for middle school certification. Grade point average must be 3.25 or better. Any previous practica must have been successfully completed.
Full time practicum in a middle school under the supervision of qualified teachers, principal, and faculty of the College of Education.

02.598 Teaching Early Childhood (6-0)6
Prerequisites: All courses required for early childhood certification. Grade point average must be 3.25 or better. Any previous practica must have been successfully completed.
Full time practicum in an early childhood setting under the supervision of qualified teachers, principal, and faculty of the College of Education.

03.612 Computer Applications in the Classroom (3-0)3 A general survey of classroom computer application: turnkey software applications, tool software, software selection, computer-video applications and telecommunications. Students will develop a computer-based lesson.

03.620 Models of Integration of Technology in the Curriculum (3-0)3
Students will explore uses of instructional television, videodisc, computers and two-way

cable systems to enhance their teaching in all curriculum areas. Curriculum development work will show due regard for an interdisciplinary approach. Students will develop a facility with technology as they learn to articulate appropriate integration in existing curriculum.

03.651 Technology and Learning Environments (3-0)3 Curriculum policies and instructional issues in the uses of technology for instruction. Students will develop a model for effective technology integration.

03.652 Technology and Schools of the Future (3-0)3 A service learning course, in which graduate students work with individual schools to consider issues of staffing, budgeting, policies, required curriculum design, physical plant, community partnerships and evaluation.

03.654 Electronic Network Applications in the Curriculum (3-0)3 Review of the instructional power of various technologies for instruction and curriculum development; videodisc, interactive video, data communication, hardware/software/facility configuration. Basic familiarity with computer operations is required for success in this course.

03.655 Research and Publishing in Electronic Environments (3-0)3 This course introduces students to research techniques in electronic environments, including the use of digital library resources and the Internet. Students are expected to produce network-publishable products. Prior experience with networked computing environments, including the Internet is required.

03.661 Curriculum Development for Technology-Based Instruction (3-0)3 Special emphasis on instructional design, scripting, formative evaluation; supplementary materials and experiences.

03.666 Issues in Distance and Distributed Education (3-0)3 A consideration of current distance and distributed learning initiatives and a review of research which may guide organizations in the design of new systems for specific populations.

03.691 Policy Issues Related to Technology (3-0)3 Consideration of the questions facing all school systems relative to access, equity, purpose, quality, uses and costs of integrating technology into the curriculum.

04.545 Museum Education at the Tsongas Industrial History Center (3-0)3 This course will deal entirely with non-traditional, non-classroom approaches to learning in a museum environment. Experiential learning in a museum environment, uses of artifacts, group activities, and individual activities will be used to construct time-restricted programs.

04.566 The Middle School Child (3-0)3 Participants will focus on understanding the growth, development and cultural influences on today's middle school child. Implications for school organization will be considered.

04.567 Middle School Curriculum (3-0)3 This course will foster the development and sharing of curricula and instructional strategies that are responsive to the needs of middle school children.

04.585 Early Childhood Education (3-0)3 Recent research and program planning requirements associated with implementing an early childhood program in schools and/or the community.

04.605 Inquiry in Science Teaching (3-0)3 An exploration of teaching science as open inquiry and guided discovery. Students will learn basic science content and methodology appropriate for K-8 students, as well as exploring nationally recognized curriculum materials.

04.606 Science Education in Urban Schools (3-0)3 Designed for curriculum leaders and science specialists. An examination and evaluation of science programs and materials appropriate for urban settings.

04.614 Constructivist Perspectives in Mathematics and Science Education (3-0)3 Traces the emergence and evolution of personal, social and radical constructivism and their influence on mathematics and science education. In particular, the works of Piaget, Vygotsky and von Glasersfeld are examined.

04.617 Advances in Mathematics, Science and Technology Education. (3-0)3 This course examines current trends and issues in the field of science and mathematics education.

04.622 Mathematics, Science, and the Educated Mind (3-0)3 Examination of the interaction of science and mathematics in the growth of knowledge, and current considerations of literacy.

04.624 Assessment in Science and Mathematics Education (3-0)3 Actual assessment and evaluation of students and/or programs, and their effect on teaching and curricula decisions will be emphasized.

04.626 Development of Concepts in Science (3-0)3 Review of the historical development of selected science concepts and the emergence of the philosophy of science. Progress in science is examined together with views of the nature of science.

04.627 Development of Concepts in Mathematics (3-0)3 Participants will analyze the nature of mathematics content knowledge and the nature of mathematics process knowledge, as well as the nature and process of knowledge acquisition. A conceptual framework will emerge from the synthesis of existing information.

04.628 Reasoning and Problem Solving in Science (3-0)3 An analysis of the development of procedural knowledge, with particular emphasis on reasoning and problem solving, as they are currently conceptualized in educational and psychological literature.

04.629 Reasoning and Problem Solving in Mathematics Education (3-0)3 Participants will analyze current literature relating to reasoning, problem solving and critical thinking. Synthesis of this literature will serve as a foundation for examining curriculum decisions.

04.634 Constructivism: A Referent for Research on Learning (3-0)3 Beginning with an examination of the work of Piaget and Vygotsky, this course will help teachers and curriculum leaders to understand the personal and social dimensions of learning in K-16 settings. Course participants are required to conduct an action research project to examine student knowledge constructions.

04.636 Theory and Research in Curriculum (3-0)3 A study of the nature of the educational experience and the creation of curricula. The contemporary theorists' views of content, concept, experience and curriculum development.

04.638 Curriculum Design: K-12 (3-0)3 A review of state mandates which, by law, shape the curriculum of the school. Examination of "new" curricula and their sources, as well as the development of a rationale for curriculum design and an evaluation of the personnel and techniques by which these curricula can be developed.

04.642 Politics of Curriculum Change: Control of Educational Programs (3-0)3 Analysis of various pressure groups that attempt to exert influence on the school curricula. Students will investigate the ideologies, mechanisms, and impacts of various political forces at the local, regional and national levels.

04.643 The Skillful Teacher (3-0)3 This course is designed to help teachers and educational leaders view teaching from a reflective stance. Teaching skills rarely identified from research on teaching; and video tapes of teaching are studied for examining the application of these skills in actual teaching practices.

04.644 Models of Teaching (3-0)3 Examination and mastery of alternative models of teaching; identification and evaluation of teaching tactics and strategies.

04.648 Teaching for Standard Certification (3-0)3 Supervised 400 hour clinical experience and seminar for teachers who hold Provisional with Advanced Standing. Permission of faculty.

04.649 Practicum Internship: Supervisor/Director (3-0)3 Supervised clinical experience in a school under the direction of both the school administrator and a college faculty member. This course is for students seeking state certification.

04.650 Practicum: Curriculum and Instruction (3-0)3 Prerequisite: Permission of Chairperson of the Faculty. Supervised clinical experience. An opportunity to apply the skills and knowledge of curriculum development and evaluation of instruction. Not for state certification.

04.655 Directed Study in Curriculum and Instruction (3-0)3 Prerequisite: Permission of Chairperson of the Faculty.

Through frequent consultation with the instructor, the student will investigate and define a problem for research and will present the findings in a significant paper. The directed study may not be substituted for a required course.

04.660 Secondary Schools in America (3-0)3 Examination of the history, current status, and future directions of schools in American society.

04.670 Issues in Curriculum and Instruction (3-0)3 Discussion of the origins of current problems in curriculum; the analysis of the viewpoints of leaders in curriculum reform; and the impact of new technologies on the direction of curriculum change are included.

04.671 Research Seminar I in Curriculum and Instruction (3-0)3 This course considers recent research in the relevant field and focuses on implications of the research for classroom and school practice. By this means it is expected that each student will identify an area of work for further study and original research for the qualifying paper.

04.672 Research Seminar II in Curriculum and Instruction (3-0)3 Continues work from preceding semester in 04.671, culminating in a research paper.

04.729 Directed Study in Mathematics and Science Education (3-0)3 Participants will develop a focused line of investigation with the supervision of a faculty member in the college. Approval of advisor is required.

04.730 Advanced Research Seminar I: Mathematics and Science Education I (3-0)3 May only be counted toward the 9 credits of dissertation research. Consideration of topics and problems associated with literature reviews of participants in mathematics or science education. Prerequisite: Successful completion of qualifying examination.

04.731 Advanced Research Seminar II: Mathematics and Science Education (3-0)3 May only be counted toward the 9 credits of dissertation research. Continued consideration of topics and problems associated with research proposals of participants in mathematics and science education. Prerequisite: 04.730.

05.620 Introduction to Educational and Human Service Administration (3-0)3 Explores how to be and what it means to be an administrator. "Grasps" of self in role and perception are related to ethical commitment.

05.622 Financial Aspects of Educational and Human Service Administration (3-0)3 Examines how moral and financial resources are marshaled and managed to meet needs of schools and human service agencies. Includes legal, economic and organizational analysis, program definition, budgeting, management and evaluation.

05.623 School Law (3-0)3 Understanding and research of legal issues, and resolutions, pertinent to educational administrators. Ethical and creative practice of "preventive law."

05.626 Educational Response to Cultural Diversity (3-0)3 The role of schools in a culturally pluralistic, industrial society. The response of educational institutions to diverse ethnic groups in earlier times. Recent legislation on public education will be examined.

05.627 Citizenship Participation in Education and Community Action Programs (3-0)3 Understanding and improving the relationships between parents and schools can be an important factor in improving the quality of education. A study of pertinent theoretical and research literature as well as specific applied situations, such as effective approaches for involving "hard to reach" parents.

05.629 Politics of Education and Human Services (3-0)3 This course contrasts the tradition of keeping politics separate from education with the realities of the educational system, and it examines the political interplay at federal, state and local levels which shapes human services programs.

05.639 Planning Process (3-0)3 Methods and theories of planning in educational and non-profit organizations. Setting goals and objectives, establishing priorities, undertaking a needs assessment for various kinds of short and long range planning.

05.640 Analysis of Educational and Human Service Organizations (3-0)3 An examination of various models of organizational analysis used to explain events and relationships in educational and human service institutions. Each student will develop a case study and analysis using organizational theory.

05.641 Issues in Staff Development (3-0)3 Includes techniques for assessing staff needs, design of alternative programs to improve staff performance, strategies to ensure productive in-service education, and approaches to program evaluation.

05.642 Principles of Supervision (3-0)3 The interdisciplinary foundations of supervision: the function of theory, research on change, individual and group relationships in organizations, staff influence processes, talent utilization, and evaluation.

05.643 Principalship K-12 (3-0)3 The scope of the principal's role, including ethical dilemmas and practical realities, is examined by shadowing, case studies, simulation, literature review and written analyses. Participants identify and evaluate the effects of alternative styles of principals.

05.644 Practicum: Educational Administration (3-0)3 Prerequisites: 05.620, 05.640, 05.639 and Permission of Coordinator. Supervised clinical experience. Students acquire practical administrative experience in an educational setting under the direct supervision of both an educational administrator and a college faculty member.

05.646 Practicum: Elementary School Principal (N-6) (3-0)3 Prerequisites: 05.620, 05.640, 05.643, 05.639 and Permission of Coordinator. Supervised clinical experience in an elementary school under the direction of both the school administrator and a college faculty member.

05.647 Practicum: Middle School Principal (5-9) (3-0)3 Prerequisites: 05.620, 05.640, 05.643, 05.639 and Permission of Coordinator. Supervised clinical experience in a middle school under the direction of both the school administrator and a college faculty member.

05.648 Practicum: School Principal (9-12) (3-0)3 Prerequisites: 05.620, 05.643, 05.639 and Permission of Coordinator. Supervised clinical experience in a secondary school under the direction of both the school administrator and a college faculty member.

05.649 Directed Study in Administration, Planning and Policy (3-0)3 Prerequisite: Permission of Faculty Chairperson. Through frequent consultation with the instructor, the student will investigate and define a problem for research and will present the findings in a significant paper. The directed study may not be substituted for a required course.

05.650 Instructional Leadership and School Reform (3-0)3 Addresses the ways in which an instructional leader initiates changes in organizations-whether curricular or in the systems which make organizations function.

05.652 Managing Change and Conflict in Schools (3-0)3 Examines theories in the changing process, strategies for effective adoption and implementation of innovations and conflict resolution.

05.658 Role of Leadership in Contemporary Thought (3-0)3 This seminar reviews works on leadership by major contemporary writers including Burns, Kellerman, Maccoby, and Peters & Waterman.

05.670 Research Seminar I in Administration, Planning and Policy (CAGS only) (3-0)3 Considers recent research in the relevant field and focuses on implications of the research for classroom and school practice. By this means it is expected that each student will identify and area of work for further study and original research for the qualifying paper.

05.671 Research Seminar II in Administration, Planning and Policy (CAGS only) (3-0)3 Involves an in-depth search and review of the literature appropriate to the student's future research.

05.729 Directed Study in Leadership in Schooling (3-0)3 Students will work on individually designed projects in leadership in schooling in close cooperation with a faculty member.

05.730 Advanced Research Seminar I:

Leadership in Schooling (3-0)3
May only be counted toward the 9 credits of dissertation research. This seminar will consider recent research in the relevant field. The implications of the research for classroom and school practice will be its focus. Each student will identify an area of work for further study and original research for the dissertation.

05.731 Advanced Research Seminar II: Leadership in Schooling (3-0)3 May only be counted toward the 9 credits of dissertation research. The second seminar will involve an in-depth search and review of the literature appropriate to the student's planned research.

06.522 Literature for Young Adults (3-0)3 The major emphasis of the course will be discussion and analysis of the goals of a literature curriculum and the exploration of various methods for achieving these goals.

06.528 Clinical Assessment of Reading and Language Disabilities (3-0)3 Prerequisites: 06.501, 06.502 (or their equivalents); A teaching certificate is required. Selection and use of procedures to make an adequate clinical and educational diagnosis. Includes the assessment of function and dysfunction in factors associated with language development; receptive, expressive, writing, reading; and the administration and interpretation of individual and group tests of perceptual, motor, and conceptual functioning in reading and language.

06.530 Reading and Thinking in the Secondary School (3-0)3 An exploration of research and theory in language-thought relationships with emphasis on the improvement of higher mental processes through instruction in listening and reading.

06.531 Organization and Supervision of Reading and Language Program (3-0)3 Organization and supervision of a reading-language program, evaluation of classroom instruction, selection of reading-language materials, coordination of the developmental program with remedial/corrective offerings, techniques of in-service education for various professional groups within a school system.

06.548 Practicum: Reading and Language Disabilities (6-0)6 Prerequisites: 06.528, and Permission of Reading and Language Coordinator. Supervised clinical experience in a school or clinical setting. (Note: Open to matriculated students only.)

06.549 Seminar in Reading and Language (3-0)3 Prerequisite: Permission of Instructor. A final course on the national and international research in reading and language and the pertinence and proposed implementation of research findings to instruction and the various roles of the reading supervisor or director.
(Note: Open to matriculated students only.)

06.602 Developmental Reading Secondary The continuum of reading skills from childhood to adulthood will be considered. Emphasis on secondary school reading.

06.603 Teaching Reading to Adults (3-0)3 This course examines recent research on adult learning and suggests a variety of effective instructional materials and strategies for teaching reading to adults in two-year colleges, in community settings, and in business and industry.

06.624 Teaching Reading Comprehension (3-0)3 Examination of the comprehension process in light of current research. Students devise teaching learning strategies which positively influence the reading comprehension of children and young adults.

06.625 Teaching of Writing (3-0)3 This course reviews the research and literature on writing instruction, grades K through 14, and examines points of view, approaches, methodologies, and materials in the area.

06.626 Teaching Study Skills, Grades 4-14 (3-0)3 An examination of research and successful teaching practices in skills and processes associated with the acquisition, assimilation, and expression of new information and ideas.

06.652 Assessment of Writing (3-0)3 This course introduces students to the vocabulary, ideas and issues necessary for understanding the nature and purpose of assessment of writing.

06.654 Evaluative Reading and Literacy (3-0)3 This course examines the theory of literacy and its direct application to instruction. The focus is on the higher level thinking skills of evaluation of written text.

06.656 Language Arts and Creativity (3-0)3 An exploration of the work on creativity, aspects of language arts and the relationships across these areas of study. Topics such as play, imagination, creative expression and problem-solving as well as attention to the dramatic arts and literature constitute the core of this course.

06.657 Responses to Literature (3-0)3 An in-depth study of theory and research on the work in readers' responses to literature. Attention is given to past findings and methodologies as well as to future research in this area.

06.661 Organization and Supervision of Language Arts and Literacy Programs (3-0)3 Several aspects of supervision such as supervisory roles and functions, models for supervision, supervision and educational improvement, and supervision and faculty development will be examined. How content and organization influence instruction, supervision and evaluation will also be considered.

06.670 Issues in Reading and Language Instruction (3-0)3 Prerequisite: Permission of Instructor. Students will study such issues as the subskills vs. holistic theory of the reading process, spin-offs from the competency testing/basic skills trend, bilingualism as related to reading instruction, uses of electronic media in the schools, relationship of L.D. instruction to remedial reading.

06.671/672 Research Seminar in Reading and Language I, II (3-0)3 / (3-0)3 Prerequisite: Permission of Reading and Language Coordinator. For CAGS students. Papers in areas related to problems in reading and language. An examination and analysis of current research at the national and international levels will be conducted, and methods of implementation and dissemination of pertinent results will be discussed.

06.673/674 Curriculum Design for English/Language Arts I, II (3-0)3/(3-0)3 This course will examine past and contemporary designs for the language arts and literature curriculum, consider the issues associated with each, and develop an English language arts and literature program for schools of the future.

06.729 Directed Study in Language Arts and Literacy (Ed.D.) (3-0)3 Students will work on individually designed projects in language arts and literacy in close cooperation with a faculty member.

06.730 Advanced Research Seminar I: Language Arts and Literacy (3-0)3 May only be counted toward the 9 credits of dissertation research. This seminar will consider recent research in the relevant field. The implications of the research for classroom and school practice will be its focus. Each student will be able to identify an area of work for further study and original research for the dissertation.

06.731 Advanced Research Seminar II: Language Arts and Literacy (3-0)3 May only be counted toward the 9 credits of dissertation research. The second seminar will involve an in-depth search and review of the literature appropriate to the student's planned research.

07.540 Research Methods for Practitioners (3-0)3 The principles and procedures of classroom-based evaluation, including instrument design and data analysis, will be discussed.

07.640 Research Methods (3-0)3 (Prerequisite for Ed.D. students) The design of research studies and the application of data analysis techniques appropriate to the research designs will be considered. Evaluation of published research in accordance with established criteria will be required.

07.642 Program Evaluation (3-0)3 Evaluation tasks will be identified and the policy issues attendant to evaluation will be examined. Students will conduct an evaluation.

07.701 Seminar in Data Analysis (3-0)3 Prerequisite: A descriptive statistics or research methods course satisfactory to the Program Faculty. This course covers basic statistics used in the analysis of educational research.

07.702 Seminar in Research Methodology and Design (3-0)3 Prerequisite: 07.701 or acceptable substitute. Methods of data collection suitable for answering a variety of

educational research questions. Considers both qualitative and quantitative strategies for research and evaluation needs.

07.703 Seminar in the Design of Research Projects (3-0)3 Students will investigate methods of data collection and analysis as they relate to the research questions and plan for the student's dissertation topic.

07.704 Qualitative Research Methods (3-0)3 This course concentrates on the use of qualitative methods for educational research. Strategies for conducting qualitative studies are described and techniques for analyzing and reporting findings are emphasized.

07.705 Survey Research Techniques and Strategies (3-0)3 Focusing on survey research methods, this course will familiarize students with the strategies, techniques, tactics, and issues in developing and administering questionnaires and interviews.

07.707 Writing for Professional Publication (3-0)3 This course will assist students: 1) to identify professional journals appropriate for publications in their fields, 2) to analyze the type of articles used, and 3) to prepare research clearly and concisely for publication.

08.659 Strategies for Instruction in Higher Education (3-0)3 A variety of theories, methods and multi-media techniques of teaching will be explored in order to familiarize students with the many options available to facilitate learning by adults.

08.660 Minorities in Higher Education (3-0)3 Focuses on the preparation, admission, retention, and achievements of minorities in higher education, both past and present.

JAMES B. FRANCIS COLLEGE OF ENGINEERING

Dean
Krishna Vedula
B. Tech., Indian Institute of Technology; M.S., Drexel University; Ph.D., Michigan Technological University.

The education of engineers in state-of-the-art areas of advanced technology and the University's commitment to national and regional economic development are the major premises upon which the graduate programs in the College of Engineering are based. These programs are intended to produce engineers whose education not only develops expertise in the design, development and production of products, but also an understanding of the management involved in the creation of new products, companies and service organizations. Thus, the graduate programs in engineering are intended to educate engineers capable of keeping abreast with the rapidly changing technology that characterizes the high technology economy of the Northeast. The programs lead to degrees of Master of Science in Engineering, Master of Science, Doctor of Science, Doctor of Philosophy, and Doctor of Engineering.

MASTER OF SCIENCE IN ENGINEERING (M.S. ENG.)

This degree is awarded in the following fields:

- Chemical Engineering
- Civil Engineering
  - Options - Environmental, Geotechnical, GeoEnvironmental, Structural, Transportation
- Computer Engineering
- Electrical Engineering
  - Option - Opto-electronics
- Energy Engineering
  - Options - Nuclear, Solar
- Materials Engineering
- Mechanical Engineering
- Plastics Engineering
  - Options - Coatings & Adhesives, Fiber/Composites

MASTER OF SCIENCE (M.S.)

The M.S. is awarded in the following fields:

- Environmental Studies
- Work Environment
  - Options - Industrial Hygiene, Occupational Ergonomics, Epidemiology, Work Environment Policy

DOCTOR OF PHILOSOPHY (PH.D.)

The Doctor of Philosophy in Physics is awarded through the College of Arts and Sciences in the following fields:

- Applied Mechanics
- Energy Engineering
- Radiological Sciences

The Doctor of Philosophy in Chemistry is awarded through the College of Arts and Sciences in the following fields:

- Biochemistry
- Environmental Studies
- Polymer Science/Plastics Eng. Option

DOCTOR OF SCIENCE (SC.D.)

The Doctor of Science degree is awarded in the following field:

- Work Environment
  - Options - Occupational Ergonomics, Industrial Hygiene, Epidemiology, Work Environment Policy

DOCTOR OF ENGINEERING (D. ENG.)

Doctor of Engineering degrees are awarded in the following fields:

- Electrical Engineering
- Mechanical Engineering

Mechanics and Materials, Manufacturing,Thermo/Fluids/Energy, and Vibrations/Dynamics
Plastics Engineering
Chemical Engineering Option
Civil & Environmental Engineering Option

The Doctor of Engineering degree is intended to equip students for engineering research at the highest professional level in organizations characterized by rapid change and ever increasing complexity.

The goal of the Doctor of Engineering program is to produce engineers who have the potential to become leaders in their organizations. To accomplish this, the program provides a doctoral level depth and breadth in a particular engineering discipline emphasizing design or clinical application. It combines this knowledge with basic courses in business and management. The technical components of the different programs are established by the faculties of the participating engineering departments. These are described in the various catalog sections.

The business, management and leadership component is common to all. The goal of this component is to supplement the student's technical knowledge with fundamental business and management skills in analysis, problem solving, decision-making, planning and action implementation. This is accomplished with courses that have been specifically designed and tailored for the engineering doctoral program by the College of Management.

The doctoral degree requires 63 semester hours of study beyond the Bachelor of Science degree. A typical program follows:

Advanced Engineering Courses and:
Seminar - 33 credits
Dissertation 21 credits
Management/Nontechnical Component 9 credits

The dissertation research involves working in leading areas of design or development, typically in collaboration with faculty and practicing research engineers. The activity may be carried on in an industrial setting, government laboratory, or on campus.

DEPARTMENT OF CHEMICAL AND NUCLEAR ENGINEERING

Department Chairperson
Alfred A. Donatelli
Professor; B.S., M.S., Lowell Technological Institute; Ph.D., Lehigh University.

Graduate Coordinator of Chemical Engineering and Materials Engineering Programs
Thomas Vasilos
Professor; B.S., Brooklyn College; Sc.D., Massachusetts Institute of Technology.

Graduate Coordinator of Energy Engineering Program (Nuclear Option)
Gilbert J. Brown
Professor; B.S., Cornell University; M.S., Ph.D., Massachusetts Institute of Technology.

Faculty:
Lee Bettenhausen
Adjunct Professor; B.S., Penn State University; Ph.D., University of Virginia.
Francis J. Bonner
Professor; S.B., Massachusetts Institute of Technology; S.M., Massachusetts Institute of Technology; Ph.D., University of Delaware; Fil. Lic., Fil. Dr. University of Uppsala.
Dominick A. Sama
Professor; S.B., S.M., Sc.D., Massachusetts Institute of Technology.
James R. Sheff
Professor; B.S., University of Colorado; M.S., Ph.D., University of Washington.
Changmo Sung
Associate Professor; B.S., Seoul National University, Korea; M.S., Ohio State University; Ph.D., Lehigh University.
Randall W. Swartz
Associate Professor; B.S., Ph.D., Rensselaer Polytechnic Institute.
John W. Walkinshaw
Professor; B.S., M.S., Lowell Technological Institute; Ph.D., Victoria University, Manchester, England.
John R. White
Professor; B.S., University of Lowell; M.S., Ph.D., University of Tennessee.

The departmental programs encompass both traditional areas of chemical and nuclear engineering and modern frontier areas such as advanced engineered materials, biotechnology, and computer aided process controls. The department encourages cooperative university-wide efforts, especially in areas such as bioengineering, materials and recycling.

COMBINED B.S./M.S. ENGINEERING PROGRAM-CHEMICAL, MATERIALS AND ENERGY ENGINEERING

A five-year B.S./M.S. Eng. program is available to undergraduates with a cumulative grade point average of at least 3.0 at the end of their junior year. See the front of the catalog for a more detailed description of this program.

MASTER OF SCIENCE IN CHEMICAL ENGINEERING DEGREE PROGRAM

The program in Chemical Engineering is designed to provide the opportunity for graduate students to study the fundamentals and applications of chemical engineering principles, and to carry out independent research.

Admission Requirements

The Department will consider students for enrollment in the Chemical Engineering program who have a bachelor of science degree in chemical engineering. Those with degrees in other areas, such as biology, chemistry, etc., are also admissible to the graduate program. However, during their course of study, they will be required to take the undergraduate courses in which they are deficient. It is highly recommended that such students complete four years of mathematics through differential equations, and one year each of organic chemistry and physical chemistry, prior to enrolling in the graduate program. Generally, such students require two to three years to complete the requirements for the M.S. degree in Chemical Engineering.

Advisors and Advisory Committee

The Program Coordinator will be the academic advisor for each student, to help remedy deficiencies in prerequisites, select electives of most value and plan the overall study program. The thesis or

project advisor will chair the advisory committee, which will guide the student in his or her research and supervise the completion of thesis or project requirements.

Plan of Study

Each student shall file an approved plan of study with the Department Chairperson and Graduate Coordinator. This form will contain a listing of the courses which will make up his or her program. Any changes must have the approval of the Department Graduate Coordinator.

Credit Requirements

The Master of Science degree in Chemical Engineering requires the successful completion of 24 credit hours of course work, excluding seminar, plus at least 6 hours in preparation of an acceptable thesis, or 27 credit hours of class work, excluding seminar, with at least 3 hours in preparation of a special project. Students who have received a teaching or research assistantship will be required to submit an acceptable thesis. Students shall enroll in at least two semesters of seminar during the period of thesis or project research.

Core Requirements

The core requirements will consist of one course in advanced mathematics, one course in thermal/fluid processes and one course in solid mechanics. A minimum of four total courses must be taken from the following core areas.

Advanced Mathematics
- 10/24.509 SystemDynamics
- 10/24.539 Mathematical Methods for Engineers

Thermal/Fluid Processes
- 10.510 Advanced Separation Processes
- 10.520 Advanced Thermodynamics
- 10.528 Advanced Transport Phenomena

Solid Mechanics
- 10.506 Interfacial Science and Engineering and Colloids
- 10.523 Electronic Materials Processing
- 10.525 Design and Packaging of Materials
- 10.531 Survey of Ceramic Materials

Thesis or Project

Each student will be required to undertake a six semester-hour thesis or a three semester- hour project and will defend the thesis or project when completed according to Graduate School regulations. During the period the student is enrolled in graduate thesis or project he or she will be required to submit to the staff of the department a brief monthly report, showing progress in his or her thesis or project and approval by his or her advisor.

MASTER OF SCIENCE IN MATERIALS ENGINEERING DEGREE PROGRAM

This program provides opportunities for advanced study and research experience in materials engineering, with concentrations in such areas as biomaterials, ceramics, composites, electronic materials, paper, polymers.

Admission Requirements

Applicants for admission to this program should have a B.S. degree or equivalent in one of the following areas:

1. chemical engineering,
2. materials science and engineering, paper engineering or paper technology from other universities,
3. related engineering and science, with correction of any deficiencies in undergraduate courses required during the graduate course of study.

Credit Requirements

The Master of Science degree in Materials Engineering requires the successful completion of 24 credit hours of course work, excluding seminar, plus at least 6 hours in preparation of an acceptable thesis, or 27 credit hours of class work, excluding seminar, with at least 3 hours in preparation of a special project. Students who have received a teaching or research assistantship will be required to submit an acceptable thesis. Students shall enroll in at least two semesters of seminar during the period of thesis or project research.

The course requirements consist of a minimum of 12 credits in graduate Materials Engineering courses forming a coherent concentration in materials such as biomaterials, ceramics, composites, electronic materials, paper, and/or polymers. A student may choose to specialize in any area of materials engineering available in the college, with approval of the Department Graduate Coordinator and Department Chairperson. In addition, the student should take the remaining courses from approved technical electives, i.e., 500 series and selected 400 series courses in Chemical Engineering in compliance with Graduate School regulations. Suitable 500 level courses from other departments in the college may be substituted, with approval of the Department Graduate Coordinator and Department Chairperson.

Plan of Study

Each student must file an approved plan of study with the Department Chairperson and Graduate Coordinator. This plan will contain a listing of the courses which will make up the student's program. The plan and any subsequent changes must have the approval of the Department Graduate Coordinator and the Department Chairperson.

Thesis or Project

Each student will be required to undertake a six semester-hour thesis or a three semester-hour project approved by the Departmental Graduate Area Committee, Graduate Coordinator, and Department Chairperson. During the period the student is enrolled in the graduate thesis or project, the student will be required to submit to the Graduate Coordinator a brief monthly progress report approved by the student's advisor. Each student will defend the completed thesis or project according to Graduate School regulations.

MASTER OF SCIENCE IN ENERGY ENGINEERING PROGRAM (NUCLEAR OPTION)

The University offers a Master of Science degree in Energy Engineering. This unique area of concentration represents a separate multidisciplinary program that is administered jointly by the Mechanical Engineering Department and the Chemical and Nuclear Engineering Department. The Energy Engineering Program has two M.S. degree options: Solar Engineering and Nuclear Engineering. Students interested in either of these program options should refer to the catalog section focused specifically on the Energy Engineering Program.

Doctoral Programs

A Doctor of Engineering degree is offered in Mechanical Engineering with options in Chemical Engineering or

Nuclear Engineering. A program leading to a Doctor of Philosophy degree in Applied Physics with an option in Energy Engineering is offered jointly by the Department of Physics and the Energy Engineering Program. For further information about these Doctoral Programs, please refer to the appropriate sections under Mechanical Engineering or Physics.

The following applies only to the Doctor of Engineering in Mechanical Engineering with an option in Chemical Engineering.

Admission Requirements

The admission requirements as set forth by the University of Massachusetts Lowell and the Department of Mechanical Engineering are to be followed.

Degree Requirements

The degree requirements as set forth by the Department of Mechanical Engineering are to be followed. This includes 33 credit hours of graduate level engineering courses in the concentration including the core requirements, 9 credit hours of D. Eng. management courses, and 21 credit hours of dissertation. There will be two concentrations in Chemical Engineering: (1) Processing and (2) Materials.

Core Requirements

The core requirements will consist of two courses in advanced mathematics, two courses in thermal/fluid processes and one course in solid mechanics. The specific courses follow:

Advanced Mathematics Thermal/Fluid Processes

10/24.509	System Dynamics
10.510	Advanced Separation Processes
10/24.539	Mathematical Methods for Engineers
10.528	Advanced Transport Phenomena

Solid Mechanics (select one of the following)

10.506	Interfacial Science and Engineering and Colloids
10.523	Electronic Materials Processing
10.525	Design and Packaging of Materials
10.531	Survey of Ceramic Materials

Elective Requirements

A total of 18 credits of courses will be taken from either the processing or the materials area. The specific courses in those areas follow:

Processing

10.506	Interfacial Science and Engineering and Colloids
10.518	Microprocessor Control
10.522	Computer-Aided Chemical Process Design
10.530	Advanced Control Strategies
10.533	Macromolecular Science and Engineering
10.535	Principles of Cell and Microbe Cultivation
10.545	Isolation and Purification of Biotech Products

Materials (in addition to the core course)

10.504	Process Calculations of Paper and Pulp Processes
10.506	Interfacial Science and Engineering and Colloids
10.523	Electronic Materials Processing
10.525	Design and Use of Packaging Materials
10.531	Survey of Ceramic Materials
10.533	Macromolecular Science and Engineering
10.535	Principles of Cell and Microbe Cultivation
24.522	Nuclear Materials
22.5xx	(Any Department of Mechanical Engineering graduate level materials course approved by the student's advisor)
26.5xx	(Any Department of Plastics Engineering graduate level materials course approved by the student's advisor)

Qualifying and Candidacy Examinations

The qualifying and candidacy examinations will be administered by the faculty in the Department of Chemical and Nuclear Engineering. The format will be consistent with the Department of Mechanical Engineering.

Dissertation

The research work for the dissertation shall be performed under the supervision of a faculty advisor in the Department of Chemical and Nuclear Engineering. At least one member of the dissertation committee shall be from the Department of Mechanical Engineering.

Administrative Requirements

The Department of Mechanical Engineering will administer the program, and the Department of Chemical and Nuclear Engineering will screen its own applicants for the program concentrations.

GRADUATE CERTIFICATE IN BIOTECHNOLOGY AND BIOPROCESSING

This graduate certificate is offered jointly by the departments of Biological Sciences and Chemical and Nuclear Engineering. The Certificate is aimed at students who hold a baccalaureate degree in science, engineering, health, or related disciplines. It may also be attractive to a person currently enrolled in a graduate degree program, as well as to someone holding a master's or doctoral degree who wishes to add or enhance his or her competency in biotechnology and bioprocessing, but does not wish to take another advanced degree. The core sequence of courses emphasizes biological and engineering principles, process concepts and the application of these to process design and improvement. The lecture and laboratory approach is supplemented by case studies and design projects that teach specific principles. Individual courses deliberately cross disciplinary barriers. This allows those with a background in the sciences to gain facility with the engineering approach to problem solving, and permits engineers to learn and apply biological principles. Concurrently, participants learn teamwork in a multidisciplinary environment and practice a result-oriented, document-driven approach to efficient project completion.

The Certificate is composed of four core courses. Refer to the appropriate section under biological sciences. The fourth course may be chosen from a list of eligible options and the selection requires the approval of the program advisor. Certificate requirements involve completion of the four courses with a 3.0 average and no more than one course with a grade of C. The four course program must be completed within a 5 year period. The core courses are offered at convenient times in order to minimize conflict with regular work schedules.

Applicants will be considered following receipt of an application form available through the Graduate School. Applicants not presently matriculated must submit an official transcript demonstrating completion of a bachelor's degree in science, engineering, or a related disci-

pline. There is no GRE or language requirement.

The courses for the Certificate may be used toward a graduate degree in either Biological Sciences or Chemical and Nuclear Engineering subject to the approval of the graduate coordinator. A grade of B or better is required for use toward a graduate degree. Qualified students may thus count the four core courses toward both the Graduate Certificate and a graduate degree.

GRADUATE CERTIFICATE IN MATERIALS SCIENCES & ENGINEERING

Contact graduate coordinator for details.

COURSE DESCRIPTIONS

Courses which are primarily Chemical Engineering are given as 10.5XX; primarily Materials Engineering 10.5XX*; and primarily Nuclear Engineering, as 24.5XX.

10.501 Paper Industry Process Analysis (3-0)3 Prerequisite: Permission of Instructor. Lectures dealing with the engineering processes of fiber separation from raw materials, fiber purification and mechanical processing of fiber and sheet formation. Chemical Engineering theory is applied to the analysis of these operations.

10.502 Principles of Chemical Engineering (3-0)3 Prerequisite: Permission of Instructor (non-majors only). An introduction to chemical process engineering for non-majors. Covers material and energy balances, thermal properties, flow sheets and gas relationships. Processes are illustrated using a variety of home work assignments.

10.504* Process Calculations of Paper and Pulp Processes (3-0)3 Prerequisite: Permission of Instructor. Analysis of various chemical engineering processes encountered in the pulp and paper industry. The course provides a review of chemical engineering principles by application to the specific design and processes encountered in this industry.

10.506* Interfacial Science and Engineering and Colloids (3-0)3 Prerequisite: Permission of Instructor. Unifying principles and the three main classes of colloids (dispersions, macromolecular solutions and micelles) are considered. Topics covered include surface tension, work and energy, effect of surface curvature, zeta potential, surface activity and diverse applications of interest to chemical engineers.

10.509 System Dynamics (3-0)3 Prerequisite: Permission of Instructor. Mathematical foundation for systems analysis using the state-variable approach. Topics include matrix methods, Laplace transforms, transfer functions, frequency response and stability analyses, and the control of distributed and lumped parameter systems. Emphasis on modeling and simulation techniques within the MATLAB/SIMULINK package. Applications to mechanical, thermal, fluid, chemical and general energy systems. A detailed course project is required. (Same as 24.509)

10.510 Advanced Separation Processes (3-0)3 Prerequisite: 10.310 or permission of Instructor. This course emphasizes separation processes requiring a rate analysis for adequate understanding, which includes most of the newer separation methods of industrial importance such as membrane, sorption and chromatographic separations. Unifying fundamental relations and concepts are emphasized. Graphical and numerical design procedures are covered.

10.518 Microprocessor Control (3-0)3 Prerequisite: Permission of Instructor. Programming methods for using minicomputers as process controllers; interfacing requirements and communications. Laboratory projects include both software and hardware components.

10.520 Advanced Thermodynamics (3-0)3 Prerequisites: Chemical or Mechanical Engineering Thermodynamics, or permission of Instructor. The central theme of this course is the appropriate use of the second law of thermodynamics in the analysis and design of commercial and industrial processes with a view toward the efficient use of our energy resources, whenever appropriate economic, environmental and social issues are integrated along with thermodynamic considerations. Areas of study include heat exchangers, heat exchanger networks, steam systems, cogeneration, refrigeration, separations and energy from biomass. Each student undertakes a term-long study of a device, process, industry, or area, usually where energy usage is significant. The objective of this study is for the student to develop the skills to become an "expert" in an energy-related area. The final report should be essentially a "consultant's" analysis, with facts, opinions and conclusions clearly presented and documented.

10.522 Computer-Aided Chemical Process Design (3-0)3 Prerequisite: Permission of Instructor. Process synthesis definition, and characterization. Introduction to modular process simulation packages such as ASPEN PLUSTM. Recycle and tear stream analysis. Stream convergence. Unit operation models. Flowsheet manipulation. Data records and physical property estimation techniques.

10.523* Electronic Materials Processing (3-0)3 Prerequisite: Permission of Instructor. Materials and processing methods in electronics and related industries; crystal growth, diffusion, etching, epitaxy, ion implantation, lithography, packaging and other topics.

10.525* Design and Use of Packaging Materials (3-0)3 Prerequisite: Permission of Instructor.
A joint course taught in conjunction with the Department of Plastics Engineering that covers the use of forest product materials, plastics, metals and glass for use as packaging materials.

10.528 Advanced Transport Phenomena (3-0)3 Prerequisite: Permission of Instructor. An advanced study of the mechanism of momentum, heat and mass transfer. The equations of continuity, motion and energy are used to examine steady and unsteady state processes. Considerable emphasis is placed upon solutions to problems.

10.530 Advanced Control Strategies (3-0)3 Prerequisite: Permission of Instructor. An introduction to computer control and to some of the common control strategies used in the design of complex chemical process control systems.

10.531* Survey of Ceramic Materials (3-0)3 Prerequisite: Permission of Instructor. Structure, properties and applications of crystalline and vitreous ceramics and ceramic coating materials. Particular attention will be paid to the interplay of processing and properties.

10.532* Principles of Chemical Engineering II (3-0)3 Prerequisite: 10.502 or Permission of Instructor. Continuation of Principles of Chemical Engineering including real gas relationships, humidity, energy balances, and the combined mass-energy balance systems.

10.533* Macromolecular Science (3-0)3 Prerequisite: Permission of Instructor.
This course emphasizes the relation of molecular and macroscopic properties and end-use to polymer synthesis and commercial manufacture. Pertinent fundamental principles are reviewed.

10.535* Principles of Cell and Microbe Cultivation (3-0)3
Prerequisite: Permission of Instructor.
This course presents the principles of biochemical engineering with an emphasis on the unit operation of cell cultivation for production of commercially important products, especially biopharmaceuticals. The bioreactor is viewed as a device for controlling the environment of recombinant and traditional cultures. Major topics include media design, kinetics of growth and production, expression systems, bioreactor types, cell physiology, and bioprocess economics.

10.539 Mathematical Methods for Engineers (3-0) 3 Prerequisite: Permission of Instructor. Ordinary and partial differential equations, linear algebra, matrix/vector calculus, numerical methods, introduction to optimization methods, and other topics as time permits. Both analytical and numerical techniques are intergrated to give good analytical skills coupled with practical problem solving tools. Extensive com-

puter work with the MATLAB package is required. (Same as 24.539).

10.540 Adhesion and Adhesives (3-0)3 Prerequisites: 10.506.
The course develops an understanding of the fundamental concepts, relations, techniques, and applications of adhesion and adhesives.

10.545 Isolation and Purification of Biotech Products (3-0)3 Prerequisite: Permission of Instructor. Efficient isolation and purification of biological products, especially proteins, from complex natural mixtures. Design project requires students to assume the role of project manager in developing a production process for a protein.

10.555 Biopharmaceutical GMP & Licensing (3-0)3 This course examines how "drugs", "biologics" and "cellular therapies" are evaluated, manufactured and sold in the United States. cGMP's, clinical trials, INDA, NDA, ANDA, PLA, ELA, validation, Q.A., Q.C., interactions with FDA staff and with company products and process development, regulatory affairs, drug metabolism, medical affairs, and production are covered in a lecture and project format.

10.586 Biotechnology Processing Projects Laboratory (0-9)3 Prerequisite: Permission of Instructor. Development of manufacturing processes for the products of biotechnology are followed through a series of process unit operations. Following the synthesis, purification and formulation of a specific enzyme throughout the course, students examine interactions between process steps and evaluate the impact of each on the total production process. As a final project, students assume the role of project team leader, developing a commercial-scale production process for the enzyme.

10.601/2 Chemical Engineering Seminar Required for all graduate students. (1-0)1

10.601/2 Materials Engineering Seminar (1-0)1 Required of all materials engineering graduate students.

10.651/2 Selected Topics in Chemical Engineering Advanced topics in the various fields of chemical engineering. Content may vary from year to year to reflect contemporary applications of chemical engineering. Credits arranged.

10.653/4 Selected Topics in Materials Engineering Advanced topics in materials engineering. Content may vary from year to year to reflect contemporary applications of materials engineering. Credits arranged.

10.720 Graduate Research in Chemical Engineering (3-0)3
Special projects undertaken by a student to expand his/her knowledge in specific fields related to his/her master's project.

10.733 Master's Project in Chemical Engineering (3-0)3 Prerequisite: Permission of Coordinator. Advanced research project required of students electing non-thesis option performed under the supervision of a senior faculty member in the Chemical Engineering Program. The project must be approved by an examining committee and the Department Chairperson.

10.733* Master's Project in Materials Engineering (3-0)3 Prerequisite: Permission of Coordinator. Advanced research project required of students electing non-thesis option performed under the supervision of a senior faculty member in the Materials Engineering Program.The project must be approved by an examining committee and the Department Chairperson.

10.743, 6 Master's Thesis Research in Chemical Engineering (3-0)3 or (6-0)6 Prerequisite: Permission of Coordinator. Advanced research work required of students electing thesis option performed under the supervision of a senior faculty member in the Chemical Engineering Program. The thesis must be approved by an examining committee and the Department Chairperson.

10.743, 6* Master's Thesis Research in Materials Engineering (3-0)3 or (6-0)6 Prerequisite: Permission of Coordinator. Advanced research work required of students electing thesis option performed under the supervision of a senior faculty member in the Materials Engineering Program. The thesis must be approved by an examining committee and the Department Chairperson.

24.505 Nuclear Reactor Physics (3-0)3 Prerequisite: Permission of Instructor. Advanced treatment of several topics in reactor physics, including cross sections and processing methods, development of transport theory, reduction to diffusion theory, and analyses of analytical and numerical solutions of the resultant balance equations.

24.506 Special Topics in Nuclear Reactor Physics (3-0)3 Prerequisite: Permission of Instructor. Potential topics include nodal methods, perturbation theory, transport theory methods, data sensitivity and uncertainty analysis, fuel management and core optimization methods, noise analysis, space-time kinetics, reactor control, reactor safety, etc. May be repeated since topics vary.

24.507 Nuclear Reactor Engineering and Safety Analysis (3-0)3 Prerequisite: Permission of Instructor. Modeling and analysis of reactor thermal-hydraulics and safety systems. Topics include nuclear heat generation and transport, single and two-phase flow, boiling crisis, and safety analysis.

24.508 Special Topics in Nuclear Reactor Engineering (3-0)3 Prerequisite: Permission of Instructor. This course will address topical issues in nuclear engineering such as advanced reactor design, proliferation resistant fuel cycles, space applications, license renewal, and decommissioning.

24.509 System Dynamics (3-0)3 Prerequisite: Permission of Instructor. Mathematical foundation for systems analysis using the state-variable approach. Topics include matrix methods, Laplace transforms, transfer functions, frequency response and stability analyses, and the control of distributed and lumped parameter systems. Emphasis on modeling and simulation techniques within the MATLAB/SIMULINK package. Applications to mechanical, thermal, fluid, chemical and general energy systems. A detailed course project is required.

24.514 Hazardous and Nuclear Waste Management (3-0)3 Prerequisite: Permission of Instructor. History of nuclear waste disposal; engineering design of disposal systems. Present status of waste and the character and quantities of future wastes. Review of disposal concepts on a generic basis. The national plan for waste disposal.

24.519 Nuclear Reactor Operator Training (0-6)3 Prerequisite: Permission of Instructor. Training, including in-reactor experience and topical lectures, as given to Reactor Operator Trainees who will undergo Federal testing for a Reactor Operator License.

24.520 Nuclear Reactor Operator Training (0-6)3 Prerequisite: Permission of Instructor. Continuation of 24.519. Upon completion of this course, the student typically will be given a simulated Reactor Operator examination, including a written test, an oral test, and a controls manipulation test.

24.522 Nuclear Materials (3-0)3 Prerequisite: Permission of Instructor. Review of metals and metal oxide properties. Radiation damage in solids, plastics, ceramics, electronics, and graphite. Hardening, embrittlement, swelling, and creep in metals. Damage mechanisms. Shielding materials.

24.539 Math Methods for Engineers (3-0) 3 Prerequisite: Permission of Instructor. Ordinary and partial differential equations, linear algebra, matrix/vector calculus, numerical methods, introduction to optimization methods, and other topics as time permits. Both analytical and numerical techniques are intergrated to give good analytical skills coupled with practical problem solving tools. Extensive computer work with the MATLAB package is required.

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

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Semester schedules, curriculum changes and new courses, visit us at http://www.eng.uml.edu/Dept/civ

MASTER OF SCIENCE IN CIVIL & ENVIRONMENTAL ENGINEERING
Program Description and General Requirements

Graduate study in Civil and Environmental Engineering is an intensive program of instruction at an advanced technical level. The program permits students to design, in consultation with their advisor, a plan of study that meets individual goals and career objectives. Program options include environmental engineering, geoenvironmental engineering, geotechnical engineering, structural engineering and transportation engineering. Admission to a particular engineering option is open to applicants with undergraduate degrees in engineering, mathematics or science.

The degree requires successful completion of 30 credit hours of course work, or 24 credit hours of instruction and a publishable thesis, or 27 hours of course work and preparation of a project report. Courses are scheduled in the late afternoon and evening to provide study opportunities for students with full-time employment. Successful completion of undergraduate prerequisite courses is required prior to registering for graduate courses. However, undergraduate prerequisites and selected graduate courses, that do not have prerequisites, may be taken during the first year of study, but only with the written permission of the student's advisor. Required undergraduate prerequisite courses are listed in descriptions of the core graduate courses shown below.

Applicants who satisfy the Graduate School admission requirements will be assigned to a faculty member who will serve as their academic advisor. Students receiving a teaching or research assistantship will normally be required to submit a publishable thesis. Those admitted to graduate study as non-degree students may apply for matriculated status. However, no more than 9 credits of work completed while in non-degree student status or transferred from another department or college will be used toward a degree. Matriculated status is preferred before initial registration and is mandatory prior to registration for second semester courses. Faculty will review a petitioner's performance in all courses attempted.

M.S. in Civil Engineering (Environmental Engineering Option)

The program offers an opportunity to pursue a broad range of interests in the fields of environmental and water resources engineering. The course of study is designed to meet an individual student's interests and career goals. Programs consist of civil engineering courses in water and wastewater treatment, environmental chemistry, hydrology, hydraulics, air pollution control, environmental law and policy and may include courses from allied disciplines such as biological and health sciences, environmental studies, chemistry and work environment. The program of study consists of four core courses and elective courses. Undergraduate core course prerequisites must be completed before beginning graduate course work.

Core Courses

14.561 Physical and Chemical Treatment Processes
14.562 Physical and Chemical Hydrogeology
14.567 Environmental Chemistry I
14.568 Environmental Chemistry II

Elective Courses

Individual student programs consist of a complement of elective courses usually taken from the following list:

14.509 Environmental Engineering Geology
14.527 Geotechnical Environmental Site Characterization
14.529 Engineering with Geosynthetics
14.564 Advanced Water Resources
14.590 Design and Analysis of Waste Containment Systems
14.592 Advanced and Innovative Concepts in Waste Containment
14.593 Physio-chemical Interactions in Earthern Barriers
14.570 Small and Alternative Waste Water Treatment
14.571 Surface Water Quality Modeling
14.572 Marine and Coastal Processes
14.573 Municipal, Industrial and Hazardous Waste Management
14.574 Air Quality Modeling
14.575 Groundwater Modeling
14.595 Hazardous Waste Site Remediation
18.501 Wetlands Ecology
18.505 Glacial Geology
18.510 Water Resources Management
18.511 Environmental Soil Science
18.523 Air Resources Management
18.530 Environmental and Natural Resource Economics
18.571 Air Pollution Phenomenology
18.581 Understanding the Massachusetts Contingency Plan

M.S. in Civil Engineering (Geotechnical Engineering Option)

The master's degree program in geotechnical engineering encompasses soil mechanics theory and applications in the fields of foundation and soil engineering. Course work emphasizes the engineering behavior of soil, soil property determination, and the use of advanced soil mechanics theory and soil-structure interaction in the solution of soil and foundation engineering problems. Elementary courses in soil mechanics, statics, strength of materials and fluid mechanics are required as prerequisites for graduate core courses. Students receiving a teaching or research assistantship are required to submit a publishable thesis.

The program of study consists of five required courses: 14.531 Advanced Soil Mechanics and any four core courses and four elective courses, selected with the consent of a student's faculty advisor. Program and course details are included in the graduate course list and the graduate catalog.

Core Courses

(select any four of the following as core courses, others may be used as electives)

14.529 Engineering with Geosynthetics
14.530 Deep Foundations
14.532 Theoretical Soil Mechanics
14.533 Advanced Foundation Engineering
14.534 Soil Dynamics and Earthquake Engineering
14.536 Soil Engineering
14.537 Experimental Soil Mechanics
14.538 Soil Behavior

Additional Elective Courses

14.504 Advanced Strength of Materials
14.507 Engineering Computation
14.509 Environmental and Engineering Geology
14.521 Reliability Analysis in Engineering
14.527 Geotechnical Environmental Site Characterization
14.529 Engineering with Geosynthetics
14.539 Ground Improvement
14.550 Behavior of Structures
14.562 Physical and Chemical Hydrogeology
14.581 Engineering Systems Analysis
14.583 Stochastic Concepts
14.590 Design and Analysis of Waste Containment Systems

M.S. in Civil Engineering (Geoenvironmental Option)

A field that encompasses the application of science and engineering principles to the analysis of the fate of contaminants in the ground; and design and implementation of schemes for treating, modifying, reusing or containing of wastes in the ground. A bachelor's degree in engineering, mathematics or science is required for admission to the program. The general areas of professional activities are:

- Characterization of geomedia with respect to stability and fluid flow properties.
- Assessment of response of terrains that host waste containment systems to natural and/or man-made hazards such as earthquakes, global warming, subsidence and floods.
- Analysis of contaminant generation and migration through porous and fractured geomaterials, and fabricated materials.
- Physico-chemical, chemical, thermal and biological treatment of wastes and contaminated geomaterials to reduce or eliminate pollutants.
- Design and analysis of surficial waste containment systems such as landfills, monofills, slurry walls, grout curtains and dewatering schemes; and deep disposal systems such as radioactive waste disposal chambers in rock.

Core Courses

14.562 Physical and Chemical Hydrogeology
14.590 Design and Analysis of Waste Containment Systems
14.593 Physio-chemical Interactions in Earthern Barriers and at least one of the following :
14.531 Advanced Soil Mechanics
14.529 Engineering with Geosynthetics
14.538 Soil Behavior
14.527 Geotechnical Environmental Site Characterization

Elective Courses

(Optional core courses may be used as electives)

14.509 Environmental/Engineering Geology

14.521 Reliability Analysis in Engineering
14.530 Deep Foundations
14.532 Theoretical Soil Mechanics
14.533 Advanced Foundation Engineering
14.534 Soil Dynamics and Earthquake Engineering
14.536 Soil Engineering
14.537 Experimental Soil Mechanics
14.561 Physical and Chemical Treatment Process Engineering
14.564 Advanced Water Resources
14.567 Environmental Chemistry I
14.568 Environmental Chemistry II
14.573 Municipal, Industrial and Hazardous Waste Management
14.575 Groundwater Modeling
14.591 Geohazards and Waste Containment System Stability
14.592 Advanced and Innovative Concepts in Waste Containment
14.594 Fundamentals of Contaminated Site Treatment Techniques
14.595 Hazardous Waste Site Remediation
18.581 Understanding the Massachusetts Contingency Plan

M.S. Civil Engineering (Structural Engineering Option)

The structural option within Civil and Environmental Engineering offers instruction and research in advanced concepts and techniques in the solution of complex structural engineering problems. A student seeking an M.S. Engineering in Structural Engineering must have a structural analysis course which includes statically indeterminate structures and junior or senior level courses in the design of steel and concrete structures. Student study programs in structural engineering are developed with a faculty advisor to meet the needs of the individual. These undergraduate courses are core graduate course prerequisites and students deficient in these areas must take these courses before they can take advanced courses.

Core Courses

14.504 Advanced Strength of Materials
14.551 Design of Steel Structures or
14.552 Design of Reinforced Concrete Structures
14.556 Finite Element Analysis (or equivalent)
14.557 Structural Dynamics

Elective Courses

14.507 Engineering Computation
14.521 Reliability Analysis in Engineering
14.550 Behavior of Structures
14.551 Design of Steel Structures
14.552 Behavior of Concrete Structures
14.553 Wood Structures
14.554 Prestressed Concrete Design
14.555 Bridge Design
14.531 Advanced Soil Mechanics
14.533 Advanced Foundation Engineering
14.536 Soil Engineering

Additional geotechnical and geoenvironmental courses and appropriate courses from the Departments of Mathematics and Mechanical Engineering may also be included in a degree plan.

M.S. In Civil Engineering (Transportation Engineering Option)

The program in Transportation Engineering offers courses in planning, design and operation of multi-modal transportation facilities. It emphasizes the interdisciplinary nature of the subject, supplementing engineering concepts with techniques from management, economics, operations research and environmental studies. It is designed to provide students with advanced technical knowledge for addressing transportation problems in a variety of practical situations. Specialization in a specific area can be achieved through thesis and project work. Graduate study plans are designed based upon student interest, professional needs and undergraduate preparation. Students are expected to have completed or show proficiency in the following courses in partial fulfillment of degree requirements:

Core Courses

14.441 Traffic Engineering
14.540 Urban Transportation Planning
14.581 Engineering Systems Analysis
14.583 Stochastic Concepts (or equivalents)

Courses from other appropriate disciplines such as engineering, management, and pure and applied science may be taken to form a coherent program in Transportation Engineering. A graduate plan of study will be designed to meet the professional needs of each student; however, at a minimum, each student is expected to have completed or show proficiency in the following courses:

Elective Courses

14.521 Reliability Analysis in Engineering
14.543 Transportation Systems Analysis
14.545 Public Transit Planning and Design
14.547 Airport Planning and Design
14.549 Traffic Flow Theory Elective

THE FIVE-YEAR B.S./M.S. ENGINEERING PROGRAM

A five-year B.S./M.S. Engineering program is available to undergraduates with a cumulative grade point average of at least 3.0 at the end of their junior year. See the front of the catalog for a complete description.

DOCTOR OF ENGINEERING PROGRAM WITH A SPECIALIZATION IN CIVIL AND ENVIRONMENTAL ENGINEERING

Program Objectives

The objective of the Doctor of Engineering Degree focus in Civil and Environmental Engineering is to develop decision-making, research-oriented engineers with the ability to produce new engineering knowledge and analyze complex, cross-disciplinary issues. Successful applicants are expected to perform advanced research in one or more areas of concentration within the Department of Civil and Environmental Engineering and successfully complete both core courses and electives that may be drawn from a variety of disciplines. Beyond the core courses, the program can be tailored to the needs of each student through a formal arrangement between the student and his or her research advisor.

Areas of Specialization

The areas of specialization within the Doctor of Engineering focus in Civil and Environmental Engineering are:

Environmental Engineering
Geoenvironmental Engineering
Geotechnical Engineering
Transportation Engineering
Structural Engineering

Program Curriculum

Students enrolled in the Doctor of Engineering program with a focus in Civil and Environmental Engineering undertake a program of study that consists of graduate courses in engineering, sciences, mathematics, and management. The program also includes oral and writ-

ten qualifying examinations and a dissertation. A minimum or 63 credit hours is required beyond the bachelor of science degree . The distribution of credit hours within the curriculum is as follows:

Civil engineering and other advanced courses - 33 credit hours; Management courses - 9 credit hours; Doctoral research dissertation - 21 credit hours

Core Courses in each doctoral program focus area

Environmental Engineering Core

14.561 Physical and Chemical Treatment Processes
14.562 Physical and Chemical Hydrogeology
14.567 Environmental Chemistry I
14.568 Environmental Chemistry II
14.595 Hazardous Waste Site Remediation

Geoenvironmental Engineering Core

14.562 Physical and Chemical Hydrogeology
14.590 Design and Analysis of Waste Containment Systems
14.593 Physio-chemical Interactions in Earthern Barriers

and at least one of the following :

14.531 Advanced Soil Mechanics
14.529 Engineering with Geosynthetics
14.538 Soil Behavior
14.527 Geotechnical Environmental Site Characterization

Geotechnical Engineering Core

14.531 Advanced Soil Mechanics

(and any four of the following:)

14.527 Geotechnical and Environmental Site Characterization
14.529 Engineering with Geosynthetics
14.530 Deep Foundations
14.532 Theoretical Soil Mechanics
14.533 Advanced Foundation Engineering
14.534 Soil Dynamics and Earthquake Engineering
14.536 Soil Engineering
14.537 Experimental Soil Mechanics
14.538 Soil Behavior
14.539 Ground Improvement

Transportation Engineering Core

14.541 Traffic Engineering
14.540 Urban Transportation Planning
14.581 Engineering Systems Analysis
14.583 Stochastic Concepts

Structural Engineering Core

14.504 Advanced Strength of Materials
14.551 Design of Steel Structures
or
14.552 Design of Reinforced Concrete Structures
14.556 Finite Element Analysis or equivalent
14.557 Structural Dynamics

A maximum of 24 hours of graduate-level course work taken at another institution with a minimum grade of B will be accepted. A maximum of 12 credits of dissertation research can be transferred from another institution to the program.

Admission to the Doctor of Engineering Program

i. Admission of Engineering Degree holders: Admission of applicants who have at least one degree in engineering from an accredited university and department requires high academic standing in all prior course work. Applicants are requested to submit GRE (aptitude part only) scores to the Graduate School. In addition to GRE scores, international students must obtain a minimum score of 550 in the Test of English as a Foreign Language (TOEFL) examination.

ii. Admission of Non-Engineering Degree holders: Admission to the Doctor of Engineering in Civil and Environmental Engineering may be offered to applicants who have a Bachelor's and/or Master's degree in non-engineering fields. In such cases, the applicant must successfully complete all requirements for a master of science in Civil and Environmental Engineering prior to being considered a candidate for the Doctor of Engineering degree.

Admission Application Process

Interested applicants are urged to contact the Graduate School for application packages and should contact the Doctoral Program Coordinator of the Department of Civil and Environmental Engineering for information about the program. The Coordinator will refer applicants to faculty members in specialization areas for more detailed information about research focus areas and the availability of graduate research assistantships. Applicants should send application packages directly to the Graduate School. The Doctoral Coordinator will review all application files in the Graduate School and circulate a complete list of all applicants to all faculty members every two months. The Coordinator will convene an Admissions Panel.

Plan of Study

i. Assignment of an Advisor and Formation of a Doctoral Committee

Within about one academic year of initiation of doctoral study, each student must work with his/her research advisor to develop a Plan of Study that complies with doctoral program and Graduate School policies. Courses substitutions, in the Plan of Study, must be reviewed by the Departmental Graduate Committee. Formal requests for substitutions are made by the student's Research Advisor. The student's Research Advisor is the supervisor of the student's research activities. The Advisor will work with the student to develop Dissertation research focus and request the service of appropriately qualified persons in the student's Dissertation Committee. The Dissertation Committee will comprise a minimum of 4 persons of which at least 2 will be full time, regular faculty members of the Department of Civil and Environmental Engineering. The function of the Dissertation Committee is to ensure that the final edition of the student's dissertation meets the high technical standards expected in doctoral work and that the student successfully defends his/her findings prior to the award of the Doctor of Engineering degree. Dissertation Committee members are not necessarily co-investigators of the student's research topic.

ii. The Qualifying Examination

Upon the completion of a maximum of 45 credit hours of graduate work that count towards the Doctor of Engineering degree, the student will apply to the Dissertation Committee to take a Qualifying Examination. In addition, students who were admitted as non-engineering degree holders into the Doctor of Engineering program must satisfy all requirements for the award of the M.S. degree in Civil and Environmental Engineering before they are allowed to take the Qualifying Examination (see section E(ii)). The Qualifying Examination may be written and oral. The Dissertation Committee members will submit their grades to the Doctoral Program Coordinator who will tally them and report the overall grade on a pass/fail basis, to the student and his/her Advisor. Students who successfully complete the Qualifying Examination will be designated as Candidates for the Doctor of Engineering degree. For each doctoral student, a maximum of two Qualifying Examinations will be allowed. A doctoral student who fails the Qualifying Examination two times will not be allowed to continue in the doctoral pro-

gram. Shortly after passing the Qualifying Examination, the Doctor of Engineering degree candidate will be expected to develop a thesis plan in collaboration with his/her advisor, and defend it successfully before the Doctoral Committee.

iii. Residency Requirements

One year of full-time residence is required of all students in the program. Residency is defined herein as a continuous period of full-time enrollment in the program or research effort at a University of Massachusetts or any other facility approved by the Doctoral Committee. Prior to graduation, a residency verification form signed by the student's Research Advisor must be submitted to the Doctoral Program Coordinator.

iv. Dissertation

Prior to the award of the Doctor of Engineering degree, each Candidate is expected to author and defend a dissertation which must represent original contributions to the field of research focus. Defense of the thesis work will be held in a seminar that will be open to the public.

COURSE DESCRIPTIONS

14.504 Advanced Strength of Materials (3-0)3 Stress and strain at a point, curved beam theory, unsymmetrical bending, shear center, torsion of non-circular sections, theories of failure, introduction to the theory of elasticity. Prerequisite 14.204 Statics.

14.507 Engineering Computation (3-0)3 Advanced software design and implementation for engineers. Structured programming using a modern language such as C. Theory and implementation of advanced data structures. Numerical algorithms for systems of equations and data manipulation. Emphasis on design and implementation of software for civil engineering purposes. Prerequisites: 25.101/102 Introduction to Engineering or equivalent.

14.509 Environmental Engineering Geology (3-0)3 The evolution of contaminated site remediation techniques and the necessity to construct above-ground and underground structures on difficult terrains have generated the need to characterize sites and improve geomedia at such sites for both environmental and structural purposes. Whereas site selection requires the analysis of environmental conditions at large spatial scales, the use of a specific site requires detailed analysis of the characteristics of geomaterials that comprise the site at much smaller spatial scales. The scope of this course covers techniques which can be applied in the analysis of geomedia with respect to their contaminant and moisture transport properties, as well as their capacity to serve as load-bearing foundations and durable construction materials. Prerequisites: Undergraduate course in physical geography, or geology/geomorphology, or 14.330 soil mechanics, or engineering geology.

14.521 Reliability Analysis in Engineering (3-0)3 A review of the elementary principles of probability and statistics followed by advanced topics including decision analysis, Monte Carlo simulation, and system reliability. In-depth quantitative treatment in the modeling of engineering problems, evaluation of system reliability, and risk-benefit decision management. Prerequisite: 14.286 Probability and Statistics for Engineers or equivalent.

14.522 Statistical Applications in Civil Engineering (3-0)3 Most of civil engineering applications must take into account the possibility of randomness. That is, the quantities that we are interested in exhibit an inherent variation that must be taken into account. This course develops a comprehensive framework in stochastic modeling, through many examples, applicable in analyses and decision making in all kinds of civil and environmental engineering problems. The emphasis in the course is placed on the application side of probabilistic techniques rather than their theoretical side with special emphasis in parametric and nonparametric statistics; reliability issues; stochastic processes; regression and simulation. Prerequisites: 14.286 Probability and Statistics for Engineers or equivalent.

14.527 Geotechnical and Environmental Site Characterization (3-0)3 This course is designed to give students a comprehensive understanding of various site investigation and site assessment technologies employed in geotechnical and environmental engineering. The course begins with introduction to site investigation planning and various geophysical methods including: seismic measurements, ground penetrating radar, electrical resistivity, electromagnetic conductivity, time domain reflectometry. Drilling methods for soil, gas and ground water sampling; decontamination procedures; and long term monitoring methods are studied. Emphasis in this course is placed on conventional and state-of-the-art in situ methods for geotechnical and environmental site characterization: standard penetration test, vane shear test, dilatometer test, pressuremeter test and cone penetration tests. Modern advances in cone penetrometer technology, instrumented with various sensors (capable of monitoring a wide range of physical and environmental parameters: load, pressure, sound, electrical resistivity, temperature, PH, oxidation reduction potential, chemical contaminants) are playing a major role in site characterization. Principles underlying these methods along with the interpretation of test data will be covered in detail. The course will also look into emerging technologies in the area of site characterization. Prerequisites: 14.330 Soil Mechanics

14.529 Engineering with Geosynthetics (3-0)3 Design, selection, testing, specifying, and constructing with geotextiles, geocomposite drains, geogrids and related geosynthetic materials for erosion control, embankment on soft soils, reinforced soil slopes (RSS), and mechanically stabilized earth walls (MSEW). Prerequisites: 14.431 Foundation and Soil Engineering or 14.531 Advanced Soil Mechanics.

14.530 Deep Foundations (3-0)3 Design and analysis of deep foundations including: Cost analysis of foundations. Effects of pile installation. Static capacity and settlement analysis of single piles and a pile group under vertical and lateral loads. Interfacial friction. Pile load test standards, construction, interpretation, and simulation. Dynamic analysis of piles, the wave equation analysis, dynamic measurements during driving and their interpretation. Caisson design, construction, and integrity techniques. Prerequisite: 14.431 Foundation and Soil Engineering or 14.531 Advanced Soil Mechanics.

14.531 Advanced Soil Mechanics (3-0)3 Theories of soil mechanics and their application. Drained and undrained stress-strain and strength behavior of soils. Lateral earth pressures, bearing capacity, slope stability, seepage and consolidation. Lab and in situ testing. Prerequisite: 14.531 Advanced Soil Mechanics or both 14.330 Soil Mechanics and 14.331 Foundation and Soil Engineering

14.532 Theoretical Soil Mechanics (3-0)3 Development and solution of the theories important in geotechnical engineering. Analytical and approximate methods of solution including finite element and finite difference. Elasticity theory for stress distributions. Upper and lower bound theory applied to retaining structures and shallow foundations. Soil structure interaction. See page and consolidation theory. Prerequisite: 14.531 Advanced Soil Mechanics or both 14.330 Soil Mechanics and 14.331 Foundation and Soil Engineering.

14.533 Advanced Foundation Engineering (3-0)3 Design and analysis of shallow foundations, excavations and retaining structures including: site exploration, bearing capacity and settlement theories, earth pressures, braced and unbraced excavations, rigid and flexible retaining structures. Prerequisite: 14.431 Foundation and Soil Engineering or 14.531 Advanced Soil Mechanics.

14.534 Soil Dynamics and Earthquake Engineering (3-0)3 Effects of dynamic loading on foundations and earth structures. Single and multiple degree-of-freedom systems. Modal analysis. Basic seismology. Stress-strain and strength behavior of soils during cyclic and dynamic loading, including liquefaction. Soil amplifi-

cation. Effect of earthquakes on retaining walls and dams. Dynamically loaded foundations. Prerequisites: 14.531 Advanced Soil Mechanics and 92.231 Calculus III.

14.536 Soil Engineering (3-0)3
The study of soil as an engineering material and its use in earth dams, road embankments, flow control, compacted fills and landfill design. Topics include: stability of slopes, unconfined flow, drains and filters, dewatering, geotechnical instrumentation and ground improvement methods. Prerequisite: 14.431 Foundations and Soils or 14.531 Advanced Soil Mechanics.

14.537 Experimental Soil Mechanics (3-0)3 Application of testing procedures to the evaluation of soil type and engineering properties. Testing for classification, permeability, consolidation, direct and triaxial shear and field parameters. The technical procedures are followed by data analysis, evaluation and presentation. Critical examination of standard testing procedures, evaluation of engineering parameters, error estimation and research devices. Prerequisite: 14.531 Advanced Soil Mechanics or 14.431 Foundations and Soils.

14.538 Soil Behavior (3-0)3 Study of the physico-chemical and mechanical behavior of soil. Topics include: soil mineralogy, formation, composition, concepts of drained and undrained stress-strain and strength behavior, frozen soils. Prerequisite: 14.531 Advanced Soil Mechanics.

14.540 Urban Transportation Planning (3-0)3 Study the characteristics and current issues of urban transportation in the United States (both supply and demand). Develop an understanding of the objectives and procedures of the urban transportation planning process. Study techniques of analysis, prediction and evaluation of transportation system alternatives. Consider the importance of economic, environmental, ethical, social and safety impacts in the design and analysis of transportation systems. Prerequisite: 14.340 Transportation Engineering or equivalent.

14.541 Traffic Engineering (3-0)3
Traffic Engineering examines the planning, geometric design and traffic operations of roads, their networks, terminals, abutting lands, and relationships with other modes of transportation. It looks at measuring traffic and travel, the study of basic laws relating to traffic flow and generation, and the application of the knowledge to the professional practice of planning, designing and operating traffic systems to achieve safe and efficient movement of persons and goods. The practice of traffic engineering can be divided into five major functional areas: Transportation Planning, Study of Traffic Characteristics, Geometric Design, Traffic Operations and Control, and Administration. Prerequisites: 14.340 Transportation Engineering or equivalent.

14.542 Intelligent Transportation Systems Seminar (3-0)3 In response to environmental, institutional, right-of-way, and fiscal constraints, intelligent transport systems embody a shift from the expansion of the transportation infrastructure to the optimization of the existing network generation through integration with advanced electronics, computers, and communications. Hallmark benefits include:

•Reduced congestion and improved traffic flow.

•Safer roads and faster emergency response.

•Seamless integration of transportation modes.

•More efficient and productive commercial transport sectors. The seminar on Intelligent Transportation Systems (ITS) focuses on the various new methods and technologies, from vehicle safety controls to traffic information and motorist assistance. The proposed technologies have important implications for the design, operation, and management of the transportation system. The state of the research, for the most mature technologies, has progressed from proposals to field tests. Experience with such systems in various countries is discussed. Prerequisites: 14.540 Urban Transportation Planning or 14.541 Traffic Engineering or permission of the instructor.

14.543 Traffic Principles for Intelligent Transportation Systems (3-0)3
The objective of this course is to introduce the student to the traffic principles that are pertinent for the planning, design and analysis of Intelligent Transportation Systems (ITS). The course is oriented toward students that come from different disciplines and who do not have previous background in traffic or transportation principles. It is designed as an introductory course that will enable the student to pursue more advanced courses in transportation systems subsequently. Prerequisites: 92.234 Differential Equations and 14.286 Probability and Statistics for Engineers or equivalent.

14.544 Transportation Planning Practice
This course reviews the characteristics and issues associated with transportation in the United States. It investigates the basic components of transportation systems and their relationship to land use activity. Principal topics covered: history of urban transportation; Capacity analysis; ISTEA; Intermodal freight transportation; Public transportation; Intelligent transportation systems; travel demand forecasting concepts and techniques; Air quality requirements; Public involvement. The course includes a term project in which the student can practice the concepts covered in the course in a hypothetical situation. This course can substitute 14.540 for satisfying core course requirements.

14.545 Public Transit: Planning & Design (3-0)3
Planning and design of public transportation systems and the technical, operational and cost characteristics of the various transit modes. Class discussions on: the impact of public transportation on urban development; the different transit modes, including regional and rapid rail transit (RRT), light rail transit (LRT), buses, and paratransit, and their relative role in urban transportation; performance of transit systems (service frequency and headway, speed, capacity, productivity, utilization, etc.); routes and networks; scheduling; terminal layout; innovative transit technologies and their feasibility. Prerequisites: 14.540 Urban Transportation Planning or 14.541 Traffic Engineering or permission of the instructor.

14.548 Pavement Design (3-0)3
Fundamentals of planning, design, construction and management of roadway and airport pavements. Introduction to the theory and the analytical techniques used in pavement engineering. Principal topics covered: pavement performance, analysis of traffic, pavement materials; evaluation of subgrade; flexible and rigid pavement structural analysis; reliability design; drainage evaluation; design of overlays; and pavement distresses.
Prerequisites: 14.340 Transportation Engineering and 14.330 Soil Mechanics or equivalent.

14.547 Airport Planning and Design (3-0)3
An airport encompasses a wide range of activities with different and often conflicting requirements. This necessitates the development of different levels of planning and design of airport facilities, which are discussed in this course. Main topics covered: Forecasting of aeronautical demand; aircraft characteristics; analysis of wind data and runway orientation; runway capacity and air separation criteria; terminal system design; access system and parking lots; financing of airports and future aviation issues. The course includes a term project where the main features of an airport (airside and landside components) are designed.
Prerequisites: 14.340 Transportation Engineering.

14.548 Traffic management and Control (3-0)3 The course presents modern methods of traffic management, traffic control strategies and traffic control systems technology. Main topics covered, include: transportation systems management (TSM) strategies; available and emerging traffic control systems technology; control concepts - urban and suburban streets; control and management concepts - freeways; control and management concepts - integrated systems; traveler information systems; system selection, design and implementation; systems management; ITS plans and programs. The course will also include exercises in the use and application of traffic simulation and optimization models such as: NETSIM, TRANSYT and MAXBAND/ MULTIBAND.
Prerequisites: 14.541 Traffic Engineering or equivalent.

14.549 Traffic Flow Theory (3-0)3
Traffic flow theory seeks to describe through precise mathematical models (a) the interac-

tions between the vehicle and the roadway system and (b) interactions between vehicles. Traffic flow theory forms the basis of all the models and procedures used in design and operational analysis of streets and highways. The course examines the fundamental traffic flow characteristics: time headway, flow, time-space trajectories, speed, distance headway and density. In depth treatment of related analytical techniques including traffic stream modeling at both microscopic and macroscopic levels, supply and demand analysis, shock wave analysis, queuing analysis and simulation modeling of traffic systems. Prerequisites: 14.541 Traffic Engineering and 14.522 Statistical Applications in Civil Engineering or 14.583 Stochastic Concepts.

14.550 Behavior of Structures (3-0)3 The use of classical and stiffness methods for analysis of structures under static loading, and the study of the effect of dynamic loading on structures. Behavior of structures, under static and dynamic loading, is emphasized in the course. Prerequisites: 14.350 Structural Analysis.

14.551 Design of Steel Structures (3-0)3 Elastic and plastic design of structural steel systems, residual stresses, local buckling, beam-columns, torsion and biaxial bending, composite steel-concrete members, load and resistance factor design. Prerequisites: 14.452 Steel Design.

14.552 Behavior of Reinforced Concrete Structures (3-0)3 Review of strength design methods for flexure and shear, anchorage, torsion, deep beams, slender columns and beam columns, deflections, slabs and walls. Prerequisites: 14.352 Reinforced Concrete Design.

14.553 Wood Structures (3-0)3 Review of properties of wood, lumber, glued laminated timber and structural-use panels. Review of design loads and their distribution in wood-frame buildings. Design of wood members in tension, compression and bending; design of connections. Prerequisites: 14.350 Structural Analysis.

14.554 Prestressed Concrete Design (3-0)3 An introductory course in the analysis and design of prestressed concrete structures. ACI/PCI Code applications. Prerequisites: 14.352 Reinforced Concrete Design.

14.556 Finite Element Analysis (3-0)3 Direct and variational methods are used to derive equations for structural elements. Static and dynamic problems are analyzed. Prerequisites: 14.350 Structural Analysis.

14.557 Structural Dynamics (3-0)3 Analysis of typical structures subjected to dynamic force or ground excitation using direct integration of equations of motion, modal analysis and approximate methods. Prerequisites: 14.350 Structural Analysis, 14.352 Reinforced Concrete Design and 14.452 Steel Design.

14.558 Bridge Design (3-0)3 Analysis and design of modern bridges, using computer software for the 3-D modeling of sample bridges under dead and live loading and seismic excitation. AASHTO specifications are used for the design of superstructures and substructures (abutments, piers, and bearings) under group load combinations. Prerequisites: 14.350 Structural Analysis, 14.352 Reinforced Concrete Design and 14.452 Steel Design.

14.559 Advanced Projects in Structural Engineering (3-0)3 Studies of topics of special interest and need of the students in structural analysis and/or design. Prerequisites: Permission of the instructor.

14.561 Physical Chemical Treatment Processes (3-0)3 The course develops the theories of physical-chemical processes used in water and wastewater treatment. Topics include adsorption processes, solubility and precipitation, heavy metal removal, aeration and gas transfer, mixing and corrosion control. Students are encouraged to use computers in solving homework problems. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 14.301 Fluid Mechanics and 14.362 Environmental Engineering I.

14.562 Physical and Chemical Hydrogeology (3-0)3 Well hydraulics for the analysis of groundwater movement. A review of the processes of diffusion, dispersion, sorption, and retardation as related to the fate and transport of organic contaminants in groundwater systems. Factors influencing multi-dimensional contaminant plume formation and migration are addressed. It is the goal of this course to provide environmental scientists and engineers with the technical skills required to understand groundwater hydrology and contaminant transport within aquifers. A term paper and professional presentation in class regarding a relevant topic is required. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I, 92.132 Calculus II and 95.141 Physics I.

14.564 Computer Hydraulics and Hydrology (3-0)3 Advanced course in civil engineering hydraulics and hydrology. Development of skills and familiarization with pressure conduit and open channel hydraulic models and Corps of Engineer and Soil Conservation Services, hydrology programs. Prerequisites: 14.301 Fluid Mechanics and 14.460 Water Resources Engineering.

14.565 Industrial Waste Treatment Processes (3-0)3 The course introduces the unit operations most commonly encountered in industrial waste treatment. Unit operation theory is first developed and then methods for data collection and data analysis are established. Specific industrial applications will be covered after an understanding of each unit operation has been developed. Each student will be required to select a specific industrial waste problem and conduct a literature search for information related to identifying waste treatment problems and their solutions regarding the selected industry. A formal research report will be generated and results will be presented in class. Prerequisites: 14.362 Environmental Engineering I.

14.567 Environmental Chemistry I (3-0)3 The environmental chemistry course sequence, Environmental Chemistry I and II, provide the essentials of chemistry needed for the study and practice of environmental science and engineering. The courses are not sequential. Environmental Chemistry I is a foundation course in inorganic equilibrium chemistry needed for advanced study of water and wastewater treatment processes and an understanding of chemical processes that occur in ground and surface waters . Basic concepts are taught utilizing, as examples, conventional water and waste treatment processes, e.g. precipitation and disinfection and reactions that can occur in clean and polluted waters. Subjects include dilute aqueous solution chemistry of acid-base and oxidation-reduction reactions, chemical thermodynamics and kinetics and coordination chemistry. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I and 92.132 Calculus II.

14.568 Environmental Chemistry II (3-0) The fate of contaminants in the environment is controlled by transport processes within a single medium and between media. The similarities in contaminant dispersion within air, surface water and groundwater will be emphasized. Interphase transport processes such as volatilization and adsorption will then be considered from an equilibrium perspective followed by the kinetics of mass transfer across environmental interfaces. A professional presentation of a select paper or group of papers concerning a course topic is required. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I, 92.132 Calculus II and 95.141 Physics I.

14.569 Advanced Projects in Water Resources (3-0)3 Studies of topics of special interest and need of students in environmental engineering and water resources design.

14.570 Small and Alternative Waste Water Treatment (3-0)3 The era of massive subsidies for construction of sanitary sewers and centralized publically operated treatment works (POTWs) has passed. Non-point pollution from sources such as onsite disposal systems has become a major focus of concern in our efforts to protect and improve ground and surface water quality. Much of the new construction in areas not already served by centralized collection and treatment must use the alternative technologies. The course is design oriented. The variously available technologies are studied in depth. Students evaluate various technologies as they may be applied to a complex problem for which information is available, and develop an optimum problem solution. Prerequisites: 14.362 Environmental Engineering I.

14.571 Surface Water Quality Modeling

(3-0)3 Theory and application of surface water quality modeling will be combined interactively throughout the course. Data from a stream will be utilized in order to bring a public domain model into operation. Prerequisites: 14.362 Environmental Engineering I and 14.460 Water Resources Engineering.

14.572 Marine and Coastal Processes (3-0)3 This course focuses on the coastal dynamics of currents, tides, waves, wave morphology and their effects on beaches, estuaries, mixing and sediment transport/accretion processes. Generalized global aspects of atmospheric and hydrospheric interactions with ocean currents are also presented. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I and 92.132 Calculus II.

14.573 Municipal, Industrial and Hazardous Waste Management (3-0)3 Characterization, handling and disposal of municipal, industrial and hazardous wastes. Technologies such as landfills, recycling, incineration and composting are examined. A term paper and professional presentation in class regarding a relevant topic is required. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I, 92.132 Calculus II and 95.141 Physics I.

14.574 Air Quality Modeling (3-0)3 This course will focus on computer application of air dispersion models. A basic understanding of the processes governing air pollution is desirable but not essential. Students will be expected to exercise gaussian plume models developed by the U.S. Environmental Protection Agency; in addition, spreadsheet calculations will be used for some analyses.

14.575 Groundwater Modelling (3-0)3 Groundwater Modeling is designed to present the student with fundamentals, both mathematical and intuitive, of analytic and numeric groundwater modeling. An introductory course in groundwater hydrology is a prerequisite for Groundwater Modeling, and the student should be familiar with IBM computers in running text editors and spreadsheets. The semester will start with basic analytic solutions and image theory to aid in the development of more complex numeric models. Emphasis will then switch to numeric groundwater flow models (MODFLOW) and the use of particle tracking models (GWPATH) to simulate the movement of solutes in groundwater. The numeric modeling process will focus on forming the problem description, selecting boundary conditions, assigning the model parameters, calibrating the model, and preparing the model report. Course topics include: Analytic Methods, Numeric Methods, Conceptual Model and Grid design, Boundary Conditions, Sources, and Sinks, and Particle Tracking.

14.581 Methods of Systems Analysis (3-0)3 The course presents methods of operations research, management science and economic analysis that are used in the design, planning and management of systems. Main topics covered, include: the systems approach, mathematical models of quantitative decision problems, optimization concepts, network models, project planning and scheduling, decision analysis, queuing systems, economic evaluation. The examples and problems presented in the course illustrate how the analysis methods are used in a variety of systems applications, such as: civil engineering, environmental systems, transportation systems, construction management, water resources, urban development, etc.

14.583 Stochastic Concepts (3-0)3 Effects of uncertainty in engineering design and decision making. Emphasis on practical applications of mathematical principles and tools of probability and statistics to problems in civil engineering. Prerequisites: 14.386 Statistics for Science and Engineering.

14.590 Design and Analysis of Waste Containment Systems (3-0)3 Proficiency in the design and analysis of systems for temporary storage and permanent disposal of wastes has become necessary for professionals involved in various technical aspects of environmental management. This course will cover the regulatory framework, design techniques and numerical analyses of several types of containment systems. The major sub-topics are: Regulations and Policies that Pertain to Containment System Design; Types and Functions of Containment Systems; Selection of Potentially Effective Systems; Design and Analysis of Landfills; Storage Tanks and Surface Impoundments; Slurry Walls and Grout Curtains; Other Containment Systems, e.g., Cryogenic Barriers, Peripheral Compaction and Ground Covers. Prerequisites: Students are expected to be proficient in simple computational methods, undergraduate level statistics, soil mechanics or engineering geology. Prior experience of practicing environmental personnel in relevant projects provides a good background for this course.

14.591 Geohazards and Environmentally Sensitive Facilities and Environments (3-0)3 Geohazards such as storms, earthquakes, floods, subsidence and global warming have significant impacts on the stability of constructed waste management facilities. This course is focused on the analysis of the characteristics of geohazards and sensitive environments in which they may occur. Approaches to mitigating environmental damages are also analyzed. The major sub-topics are: Types and distribution of sensitive geological environments; Spatial and temporal risk analysis for site zonation and selection, and facility design; Analysis of potential failure modes in seismic zones, permafrost, wetlands, floodplains, karst and subsiding areas; Airphoto interpretation and site characterization techniques; Design modifications to counteract geohazards. Prerequisites: Successful completion of an undergraduate course in physical geography, or geology/geomorphology, and soil mechanics (or geotechnical engineering) or engineering geology.

14.592 Advanced and Innovative Concepts in Waste Containment (3-0)3 The development of effective schemes for controlling human and environmental exposure to stored contaminants in constructed systems such as landfills, radioactive waste repositories and liquid waste storage tanks requires integrated analyses. This course covers: Integration of ecosystem, toxicological and geotechnical risks; Modeling of one-dimensional extraction of contaminants in barriers; Application of reliability techniques; Principles and design of biokinetic, cryogenic, rhizo, reactive (attenuative), capillary and electrokinetic barriers; Analysis and design of mitigative geotechnical foundations for radon intrusion control, and buildings on contaminated/reclaimed sites. Prerequisites: Successful completion of 14.590, Calculus I and an undergraduate course in soil mechanics is required prior to enrollment in this course.

14.593 Physico-Chemical Interactions in Earthen Barriers (3-0)3 This course focuses on the mechanisms by which chemical contaminants react with earthen components of containment systems. The objective is to explore physico-chemical phenomena that may occur at the microscopic scale but have macroscopic physical manifestations which could determine the long term performance of waste containment systems. The effects of physico-chemical interactions on barrier characteristics such as permeability, contaminant distribution coefficient and diffusion coefficient are analyzed. Some of the major sub-topics covered are: Earthen barrier mineralogy and crystal chemistry; Thermodynamic basis for contaminant retardation, barrier material flocculation, dissolution, leaching and weathering; Application of microscopy and other imaging techniques; Hydrothermal alteration and mercury porosimetry. Prerequisites: Students are expected to have completed an advanced undergraduate class in physical chemistry or soil chemistry. Prior completion of 14.567, Environmental Chemistry I or concurrent enrollment is encouraged.

14.594 Fundamentals of Contaminated Site Treatment Techniques (3-0)3 This course focuses on the principles of hazardous waste site assessment and treatment using physical and chemical remediation technologies. Both established and emerging remediation technologies will be addressed. Among the topics covered are: Site contamination scenarios; Site characterization techniques; Contaminant release mechanism; Exposure assessment; Site ranking techniques; Waste classification; Solidification/stabilization; Oxidation/reduction; Thermal treatment; In-situ vitrification; and Hydraulic fracturing. (Additional technologies are covered in

Course 14.595.) Prerequisites: Completion of two semesters of Introductory Chemistry is required. Previous completion of courses in basic-level environmental engineering, soil science, or engineering geology is also an advantage. Students are expected to be proficient in basic computational methods. Prior experience of practicing environmental personnel in relevant projects provides a good background for this course.

14.595 Hazardous Waste Site Remediation (3-0)3 This course focuses on the principles of hazardous waste site remediation (with an emphasis on organic contaminants) using physical, chemical or biological remediation technologies. Both established and emerging remediation technologies including: bioremediation, intrinsic remediation, soil vapor extraction (SVE), in situ air sparging (IAS), vacuum- enhanced recovery (VER), application of surfactants for enhanced in situ soil washing, hydraulic and pneumatic fracturing, electrokinetics, in situ reactive walls, phytoremediation, and in situ oxidation, will be addressed. A term paper and professional presentation in class regarding a relevant topic is required. Prerequisites:, 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I, 92.132 Calculus II, 95.141 Physics I and 14.562 Physical and Chemical Hydrogeology is highly recommended.

14.651 Special Topics in Civil Engineering (3-0)3 Course content and credits to be arranged with instructor who agrees to direct the student.

14.693 Individual Projects in Civil & Environmental Engineering (3-0)3

14.705 Supervised Teaching in Civil & Environmental Engineering (3-0)3

14.733 Master's Project in Civil Engineering (3-0)3

14.743, 6 Master's Thesis in Civil Engineering (3-0)3, (6-0)6

MASTER OF SCIENCE IN ENVIRONMENTAL STUDIES

Department Head and Graduate Coordinator

William B Moeller
Professor of Civil Engineering; B.S., Villanova University; M.S., Ph.D., University of Connecticut, P.E.

Associated Faculty:

Clifford J. Bruell
Professor of Civil Engineering, B.S., Lowell Technological Institute; M.S., University of Lowell; Ph.D., University of Connecticut.

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Hillary I. Inyang
University Professor; B.S.,(Geology), University of Calabar; B.S. (C.E.), M.S., North Dakota State University; Ph.D., Iowa State University.

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Charles R. Ott
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Bodo W. Reinisch
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Susan Woskie
Associate Professor of Work Environment, Ph.D., Clark University.

(Semester schedules, curriculum changes and new courses visit us at http://www.eng.uml.edu/Dept/civ)

MASTER OF SCIENCE DEGREE PROGRAM

This interdisciplinary program offers a Master of Science in Environmental Studies with a thesis or a non-thesis track. Enrollment in the program is open to individuals with a baccalaureate degree in technology, biology or a physical science. Others may be admitted with the approval of the Graduate Coordinator. Such students may make up course prerequisite deficiencies while in the program, although those credits will not count toward the total required for the master's degree. Frequently, students entering the program are required to take a number of undergraduate courses to develop analytical skills and to prepare for advanced level course work. Undergraduate courses may include calculus, statistics, chemistry, computer programming or courses designed to develop problem-solving skills. Course requirements are determined by discussion with the Program Coordinator.

The thesis track requires completion of an approved program of study involving a minimum of 24 credits of core courses and electives, and 6 credits of thesis, consisting of laboratory research or scholarly investigation, for a total of 30 credits. Students may only register for thesis research with the prior approval of a thesis advisor. The thesis work is to be guided by a principal advisor who is a member of the University of Massachusetts Lowell faculty and by two additional committee members, at least one of whom must be a member of the faculty. Committee selection and the thesis topic are subject to the approval of the graduate coordinator.

The non-thesis track requires completion of an approved program of study involving 30 credits of core courses and electives. All individual programs of study must include the core courses listed below:

Core Courses

18.510 Water Resources Management
14.573 Municipal, Industrial and Hazardous Waste Management
18.523 Air Pollution Control or
18.571 Air Pollution Phenomenology

Elective Courses

14.509 Environmental/Engineering Geology
14.561 Physical and Chemical Treatment Processes
14.562 Physical and Chemical Hydrogeology
14.564 Advanced Water Resources
14.567 Environmental Chemistry I
14.568 Environmental Chemistry II
14.570 Small and Alternative Wastewater Treatment
14.571 Surface Water Modeling
14.572 Marine and Coastal Processes
14.574 Air Quality Modeling
14.575 Groundwater Modeling
14.595 Hazardous Waste Site Remediation
18.501 Wetlands Ecology
18.502 Limnology
18.503 Environmental Toxicology and Risk Assessment
18.505 Glacial Geology
18.511 Environmental Soil Science
18.512 Geology and Evaluation Techniques
18.516 Topics in Geomorphology
18.517 Soil Physics
18.519 Introduction to Microbiology
18.525 Epidemiology for Environmental Studies
18.527 Environmental Laws
18.530 Environmental and Natural Resource Economics
18.571 Air Pollution Phenomenology
18.572 Energy and the Environment
18.575 Physical Chemistry for Environmental Studies
18.576 Boundary layer Meteorology
18.577 Remote Sensing of the Atmosphere
18.578 Advanced Synaptic Meteorology
18.580 Implementation of Environmental Policy
18.581 Understanding the Massachusetts Contingency Plan
84.519 Environmental Chemistry III

PH.D. PROGRAM IN CHEMISTRY ENVIRONMENTAL STUDIES OPTION

A Ph.D. in Chemistry with an option in Environmental Studies is offered jointly by the Department of Chemistry and the Department of Civil Environmental Engineering. The program is described in detail in the Chemistry Department section of this catalog.

COURSE DESCRIPTIONS

18.501 Wetland Ecology (3-0)3 Types, characteristics and definitions, functions and values, regulation and management of wetlands; with due regard given to geology, soils and hydrology, and biological/ecosystem interations.

18.502 Limnology (3-0)3 Study of functional relationships and productivity of freshwater communities as affected by physical, chemical and biological components of the environment. Emphasis on lakes and ponds, man-made stresses on systems, tools for diagnosis and restoration.

18.503 Environmental Toxicology and Risk Assessment (3-0)3 Basic toxicological principles, spectrum of effects with emphasis on mammals, predicting fate of chemicals, assessing potential exposure, prediction of exposures. Case studies of major health hazards, issues of regulation. Strong interdisciplinary approach.

18.505 Glacial Geology (3-0)3 The course will examine how study of nature, origin and history of glacial events can allow the residual soils and landforms to be dealt within a meaningful comprehensive manner in investigations of groundwater, environmental and engineering problems.

18.510 Water Resources Management (3-0)3 Concepts and methodologies of hydrology, constraints and objectives of water resources management, and the interrelationship between hydrologic and managerial components of water resource issues. Case studies are reviewed and discussed.

18.511 Environmental Soil Science (3-0)3 Prerequisite: introductory chemistry. Discussion of physical, chemical and biological soil properties in relation to environmental issues. Principles of soil physics, soil mineralogy, soil formation and classification, soil fertility, soil management and mineralogy. Role of soils in agronomic systems, wastewater disposal, and wetland delineation. Impact of land use and associated practices on soil pollution and related water quality issues.

18.512 Geology and Evaluation Techniques (3-0)3 The course will examine the application of techniques such as seismic, resistivity, and gravinometric testing for the analysis and evaluation of various geologic conditions.

18.516 Topics in Geomorphology (3-0)3 A study of selected physical and chemical processes at work on the earth's surface which result in the formation and development of landforms. Emphasis is placed on understanding processes and the application of that knowledge to environmental problems.

18.517 Soil Physics (3-0)3 Physical properties of soils and how they relate to the movement of water, solutes, and contaminants in saturated and unsaturated soils. Methods of measuring and characterizing physical properties of soils. Applications to environmental problems, including land-based disposal systems, hazardous waste site investigation and remediation, and soil-water management.

18.519 Introduction to Microbiology (3-0)3 An introductory course focusing on

the significance of micro-organisms in man's environment, and the physical, chemical and biological processes governing their behavior and fate in ecosystems.

18.523 Air Pollution Control (3-0)3 Air pollutants, their sources, emission rates, ambient concentrations, effects on health, animals and vegetation including aquatic life. The Clean Air Act, National Ambient Air Quality Standards, New Source Performance Standards, Prevention of Significant Deterioration. Monitoring at emission sources and in the ambient; exceedances and enforcement. Air pollution modeling as a tool of permitting and enforcement. Emission control technologies and strategies. Local, regional and global air resources management.

18.525 Epidemiology for Environmental Studies (3-0)3 The study of the distribution and determinants of disease in human population and how these diseases are disseminated by environmental changes. The methods used in conducting epidemiological investigations including descriptive analytical and experimental studies, patient care and cohort studies.

18.527 Environmental Laws (3-0)3 The large body of law which has developed since the early 1960's is examined in considerable detail. Federal laws relating to the environment, particularly with the Environmental Protection Agency and the Occupational Safety and Health Acts. State and local laws and ordinances are discussed where pertinent.

18.530 Environmental and Natural Resource Economics (3-0)3 The development of concepts and methods of economic analysis with a view toward their application for preserving the environment. An analysis of economic growth and the usage of depletable resources. Appraisal of quantitative methods for measuring environmental damage and the cost of abatement.

18.571 Air Pollution Phenomenology (3-0)3 Air pollutants: their sources, emission rates, ambient concentrations and trends. National and international standards for emissions and ambient concentrations. Air pollution meteorology: atmospheric structure and dynamics. Air pollutant dispersion and transport. Photooxidant pollutants: precursors and products. Particular matter: primary and secondary particles, their dispersion, transport and deposition on a local and regional scale, including regional haze (visibility impairment). Acid deposition: precursors and products, their transport, dispersion, dry and wet deposition. Global air pollution, e.g. stratospheric ozone depletion and greenhouse effect.

18.572 Energy and the Environment (3-0)3 Laws that govern the conversion of energy from one form to another. Flow of energy in our present industrial society from extraction through transport and conversion to end use. Electricity: generation from fossil fuel, nuclear, hydro, solar and other sources; its distribution and end use. Air, water and soil pollution from all sources of energy on a local, regional and global scale. Amelioration of environmental effects by emission control, fuel switching, renewable energy and conservation.

18.573 Air Pollution Laboratory (1-4)3 Instruments and apparatus applied to monitoring and chemical analysis of air pollutants, gaseous and particles (aerosols). Physicochemical fundamentals of air pollutant monitoring and analysis. Standard monitoring of "criteria" pollutants (CO, Of, Nox, SO, total hydrocarbons, size-fractioned particles) and other pollutants (lead and other metal vapors, speciated organic compounds). Analytical techniques (gas chromatography, chemiluminescence, mass-spectrometry, flame ionization, atomic and molecular emission and absorption spectroscopy). Data collection, archiving and analysis. Use of data in air pollution modeling.

18.575 Physical Chemistry for Environmental Studies (3-0)3 Physical chemistry principles related to environmental systems, processes and measurements. Topics include thermodynamics, thermochemistry, collision processes, chemical kinetics in the gaseous phase and solution, including heterogeneous reactions and catalysis, oxidation-reduction, electrochemistry, changes of state, adsorption, absorption, diffusion and osmosis, atomic and molecular structure, atomic and molecular spectroscopy.

18.580 Implementation of Environmental Policy (3-0)3 Development and analysis of information on policy issues; development of strategies for implementation. Case studies, practitioner seminars and student projects employed.

18.581 Understanding the Massachusetts Contingency Plan (3-0)3 The Massachusetts Contingency Plan (MCP) is a body of regulations designed to streamline and accelerate the assessment and cleanup of releases of oil and hazardous materials to the environment. This course serves as an introduction to the MCP and will explore the intent and use of key aspects of this working document. Though primarily a regulatory course, some topics to be covered are technical by nature. Prerequisites: None. Though not required, some familiarity with relevant environmental science and/or engineering principles is desirable.

Semester schedules, curriculum changes and new courses: visit the Department of Civil and Environmental Engineering's web site at http://www.eng.uml.edu/Dept/civ.

MASTER OF SCIENCE IN ENVIRONMENTAL STUDIES (ATMOSPHERIC SCIENCES CONCENTRATION)

Enrollment in this program is open to individuals with a baccalaureate degree in sciences, mathematics and engineering. Others may be admitted with the approval of the Graduate Coordinator. Such students may make up course prerequisite deficiencies while in the program, although these credits will not count toward the total required for the master's degree. Frequently, students entering the program are required to take a number of undergraduate courses to develop the analytical skills, and to prepare for the advanced level courses.

The M.S. program requires the completion of 30 credits, 9 in core courses, and 15 in elective courses listed below. Six credits are achieved by completing a Masters Thesis. The thesis involves original laboratory or theoretical work, usually publishable in accredited and peer reviewed technical journals. With the Graduate Coordinator's approval, the thesis work may be performed at home or at the student's employment facilities. The thesis advisory committee will consist of a Principal Advisor who is the member of EEAS faculty, and two members from CEE, associated faculty or external advisor, the latter with the approval of the Graduate Coordinator. Most of the courses will be offered in the evening, usually from 6 to 9 pm, once per week. This enables working students to complete the course requirements while the student is employed. A maximum of 5 years is allowed for completion of the master's degree, including the thesis.

Core Courses

85.501	Boundary Layer Meteorology
87.575/ 84.575	Physical Chemistry for Environmental Studies
	Chose one of the two following courses:
19.527	Environmental Law and Policy
49.615	Environmental and Natural Resources Economics

Elective Courses

85.502	Advanced Synoptic Meteorology
85.503	Remote Sensing of the Atmosphere
85.511	Solar Terrestrial Relations
85.515	Atmospheric Structure and

	Dynamics
85.523	Air Pollution Control
85.571	Air Pollution Phenomenology
85.673/	Air Pollution Laboratory/Meas-
19.617	Measurement of Airborne Contaminants
85.674	Air Quality Modeling
87.572	Energy and the Environment
19.514	Aerosol Science
92.550	Mathematical Modeling
98.613	Environmental Monitoring and Surveillance (Radionuclides)

COURSE DESCRIPTIONS

85.501 Boundary Layer Meteorology (3-0)3 This course will draw upon the equations of motion in the atmosphere to develop a theoretical understanding of the atmospheric boundary layer. This understanding will be compared with real observations, both taken with the Department's rawinsonde equipment, as well as published data. The emphasis will be on blending theory and practice to enhance the student's understanding of the behavior of the atmosphere.

85.502 Advanced Synoptic Meteorology (3-0)3 This course is designed for graduate students who have a strong background in mathematics and physics, but whose meteorology preparation is weak. The basic concepts of weather forecasting and analysis on synoptic scales will be covered both theoretically as well as in application to case studies and current weather. Each student will be required to make 25 forecasts during the course of a semester. This will encourage the development of three-dimensional visualization techniques and an appreciation of weather systems.

85.503 Remote Sensing of the Atmosphere (3-0)3 This course is a survey of ground based, balloon, rocket probe, radar and satellite remote sensing techniques. Optical and radio frequency remote sensing techniques are surveyed. The focus is on the determination of physical, chemical and dynamical quantities by remote sensing measurements. The theory presented is used to interpret data obtained by remote sensing techniques. Various inversion methods discussed are used to obtain spatial discrete quantities from line-of-sight observations. Modeling and simulation techniques are described and practiced.

85.511 Solar Terrestrial Relations (3-0)3 As part of the solar system the earth and its atmosphere is coupled through the earth's plasmasphere and magnetosphere to the sun's electromagnetic and corpuscular radiation. Starting with a discussion of the upper atmosphere (mesosphere and thermosphere) the course will develop the photo-ionization processes in the ionosphere, and the ground-based and space techniques for the exploration of the upper atmosphere. An introduction will be given to the collisionless plasma processes in the magnetosphere leading to the concept of space weather. Solar activity, coronal mass ejection and solar wind effects on the magnetosphere will be introduced, and the phenomena of magnetic storms and their effects on electrical power systems will be explained.

85.515 Atmospheric Structure and Dynamics (3-0)3 The temperature, pressure and density structure of the atmosphere are reviewed, as well as the chemical composition. Topics include atmospheric and solar radiation, atmospheric heat budget and the hypsometric equation. Dynamics of the atmosphere explores the behavior of fluids on a rotating earth, global circulation, synoptic scale motions, perturbation theory of wave motions. Elements of climatic change and the effects of anthropogenic emissions on climate and weather will also be discussed.

85.523 Air Pollution Control (3-0)3 This course describes air pollutants, their characterization, ambient concentrations, effects on human health and the ecology, and the environmental laws and regulations that set standards on emission rates and ambient concentrations. The basics of air pollutant dispersion and transport are also covered. The main focus of the course is on emission control technologies for particulate matter, carbon monoxide, sulfur oxides, nitrogen oxides, organic and inorganic toxic pollutants. The following technologies are discussed: cyclones, scrubbers, electrostatic precipitators, bag-houses, adsorption, absorption and incineration. The automobile and its emission control are reviewed. Alternative methods are also discussed, such as fuel substitution, conservation and efficiency improvement.

85.571 Air Pollution Phenomenology (3-0)3 The course centers on transport, dispersion and transformation of air pollutants in the atmosphere. The atmospheric structure and dynamics are reviewed. The atmospheric dispersion equation is developed for instantaneous and steady state releases of pollutants, including the Gaussian Plume Equation for point, line and area sources. The sources and transport of particulate matter are discussed, including haze and visibility impairment. Other topics are photo-oxidants (ozone), acid deposition, stratospheric ozone depletion and the greenhouse effect.

85.673/19.617 Air Pollution Laboratory/Measurement of Airborne Contaminants (3-0)3 Prerequisite: 85.571 Air PollutionPhenomenology. This laboratory course is jointly offered by the Departments of EEAS and Work Environment. The student gains practice in operating standard apparatuses for measuring air pollutants in the outdoor and indoor air. The techniques employed are photometry, spectroscopy, chemi-luminescence, mass-spectrometry, gas chromatography and particle collection and analysis.

85.674 Air Quality Modeling (3-0)3 This course focuses on computer applications of air dispersion models. Students will be expected to exercise the Gaussian plume models developed by EPA. Also, reactive-dispersion modeling will be practiced, that is, models in which primary pollutants react with themselves, or with atmospheric species to produce secondary pollutants. Examples are acid deposition, photo-oxidant and aerosol models. In addition, spreadsheet calculations will be used for some analyses. A prerequisite to this course is 85.571 Air Pollution Phenomenology.

87.572 Energy and the Environment (3-0)3 This course discusses the world and U.S. primary energy resources and consumption, including fossil, nuclear and renewable energy sources. Principles of thermodynamics are reviewed, especially in regard to energy usage efficiency improvement. A significant part of the course is devoted to electricity production, including site visits to fossil and nuclear power plants. The environmental effects are discussed of energy extraction and consumption, such as SOx, NOx and particulate matter emissions, acid deposition, the greenhouse effect, radioactive waste disposal. Also the risks of accidents are discussed in fossil and nuclear fuel usage.

87.575/84.575 Physical Chemistry for Environmental Studies (3-0)3 This course covers the physical chemistry principles that are related to environmental systems, processes and measurements. Topics include fundamental aspects of thermodynamics, thermochemistry, collision processes, chemical kinetics in solution and the gas phase, heterogeneous reaction and catalysis, water chemistry (drinking, ground and waste water), oxidation-reduction, electrochemistry, changes of state, adsorption, absorption, diffusion, osmosis, atomic and molecular structure, atomic and molecular spectroscopy, and radioactivity.

19.514 Aerosol Science (3-0)3 This course describes the basic properties of airborne particles, with particular regard to properties important to health. Content includes uniform particle motion, particle collection mechanisms, filtration, particle sampling and analysis, respiratory deposition, particle statistics, electrical and optical properties. The course includes lectures and laboratory practice.

92.550 Mathematical Modeling (3-0)3 This course is devoted to studying the application of mathematics to real life problems from the physical, biological, social and behavioral sciences. Experience is provided with a wide variety of models (deterministic, stochastic, simulation, continuous, discrete, axiomatic). Computer use in solving problems is encouraged.

19.550 Environmental Law and Policy (3-0)3 Survey of relevant environmental laws and their application to public policy. A framework for understanding environmental

policy will be developed. The course focuses particularly on laws and regulations pertaining to environmental and work place protection. State and local laws and ordinances are also discussed.

49.615 Environmental and Natural Resources Economics (3-0)3 This course introduces students to the economic and policy aspects of environmental quality and natural resources issues. Standard benefit cost and efficiency criteria are used to analyze a wide variety of environmental and natural resources problems. Topics covered include basic theory of environmental and natural resource economics; sustainable development; economics of pollution control; economics of renewable and recyclable resources; energy economy and environmental interaction models.

98.613 Environmental Monitoring and Surveillance (Radionuclides) (3-0)3 Sources of environmental radioactivity; design of monitoring programs; sampling and analytical measurement programs for specific radionuclides and external radiation sources; analytical equipment and procedures; design of an environmental laboratory; and quality assurance programs.

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

Department Head
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M.S. Eng. Program Coordinator
F. Ross Holmstrom
Professor: B.S., University of Washington; M.S., Ph.D., Stanford University.

Doctoral Program Coordinator
Dikshitulu Kalluri
Professor; BE, Andhra University; M.S., University of Wisconsin; D.I.I.Sc., Indian Institute of Science; Ph.D., University of Kansas.

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Professor; B.S., B.S., Madras University; Banaras Hindu University; M.S.E., Princeton University; Ph.D., University of Pennsylvania.
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E. Russell Laste, Jr.
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Tenneti C. Rao
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H. James Rome
Associate Professor; B.S., M.S., University of Michigan; Ph.D., University of Pennsylvania.
Ziyad M. Salameh
Professor; B.S., Moscow Power Engineering Institute, USSR; M.S., Ph.D., University of Michigan.
Gary S. Sales
Associate Professor; B.S., Brooklyn College; M.S., Ph.D., Pennsylvania State University.
Stephen J. Spurk
Associate Professor; B.S., Merrimack College; M.S., University of New Hampshire.
Charles Thompson
Professor; B.S., New York University; M.S., Polytechnic Institute of New York; Ph.D., Massachusetts Institute of Technology.
Anh Tran
Professor; B.S., National Taiwan University; M.S., Ph.D., University of Rhode Island.
Fahd G. Wakim
Associate Professor; B.S., American University of Beirut; M.A., Ph.D., University of Texas.
Jay A. Weitzen
Professor; B.S., M.S., Ph.D., University of Wisconsin, Madison.
A. David Wunsch
Professor; B.E.E., Cornell University; S.M., Ph.D., Harvard University.

Areas of Study and Degrees

The Department offers graduate courses in the following Disciplinary Areas:

- Digital Technology & Computer Engineering
- Electromagnetics & Properties of Materials
- Power & Energy Engineering
- Microelectronics, Optoelectronic Materials, Circuitry & Systems
- Telecommunications & Information Engineering

Graduate thesis research currently is under way in the following technical areas, many of which fall across the boundaries of the disciplinary areas listed above:

- Advanced Computation
- Digital Design
- Digital Systems
- Electromagnetics and Wave Propagation
- Electrooptics, Optics, and Optical Information Processing
- Information and Communications
- Micro-and Minicomputer Applications
- Microwave Devices, Circuits and Systems
- Power Apparatus and Systems
- Semiconductors and Microelectronics
- Signal and Image Processing
- VLSI Circuits and Systems

The Department awards the following graduate degrees:

- M.S. Eng. in Electrical Engineering
- M.S. Eng. in Computer Engineering
- D. Eng. in Electrical Engineering

MASTER OF SCIENCE IN ENGINEERING PROGRAMS

M.S. students are strongly encouraged to undertake an M.S. thesis. A master's degree will be awarded upon satisfactory completion of 30 credit hours of study in the thesis track of which the thesis provides 6 credit-hours. Thirty-three credit hours of study are required in the non-thesis track, including the 3 credit hour research review course 16.699 or advanced project course 16.733. Students may pursue the Opto-Electronics Option in the M.S. program in Electrical Engineering.

B.S./M.S. PROGRAM

The five year B.S./M.S. program is available in both M.S. programs to undergraduates with a cumulative grade point average of at least 3.0 at the end of their junior year. Students must apply for this program no later than the end of their junior year. See description in the front of this catalog.

Admission to the M.S. Eng. Programs in Electrical or Computer Engineering

In addition to the requirements listed on page 15 in this catalog, applicants must submit the application materials supplied by the Graduate School as well as the official score report for the Graduate Record Examination Aptitude Test. The TOEFL exam is required of students from abroad whose native language is not English.

M.S. ENG. PROGRAM IN ELECTRICAL ENGINEERING

In addition to the requirements listed on page 15 in this catalogue, applicants to the M.S. Eng. program in Electrical Engineering should have received a B.S.E.E. or equivalent degree with acceptable quality undergraduate work from an accredited college or university. Students lacking the B.S.E.E. who hold a bachelor's degree in physical science, mathematics, computer science, or engineering must have a knowledge of circuit theory, and must have completed the following courses (and the prerequisites for these courses as required) at UMass Lowell, or equivalent courses at another recognized college/university where they are offered as part of a B.S.E.E. curriculum. Credits are indicated in parentheses.

- 16.217 Microcomputer Operations and Programming (3)
- 16.265 Logic Design (3)
- 16.362 Signals and Systems (3)
- 16.365 Electronics (3)
- 16.311 Electronics Lab I (2)
- 16.413 Linear Feedback Systems (3)
- 16.360 Electromagnetic Theory I (3)

M.S. ENG. PROGRAM IN COMPUTER ENGINEERING

To be eligible for admission to the master's degree program in Computer Engineering, the applicant must have received a bachelor's degree or equivalent in a physical science, computer science, mathematics or an engineering discipline, from an accredited college or university, with acceptable quality undergraduate work.

The following undergraduate areas of study are prerequisites for the M.S. Eng. program in Computer Engineering. Credits are indicated in parentheses.

- Calculus (6)
- Advanced Mathematics (6)
- Circuit Theory, Electronics and Associated Laboratory (9)
- Combinational & Sequential Logic Design and Laboratory (3-6)
- FORTRAN, Pascal, or C (3)
- Microcomputer Operations and Programming (3)

Academic Advisor

Each graduate student admitted to the Electrical & Computer Engineering Department is assigned an academic advisor who will assist him or her in the selection of courses and who will develop with the student a program which will meet his or her requirements for the desired degree.

M.S. ENG. IN ELECTRICAL ENGINEERING REQUIREMENTS

Electrical Engineering Core Requirement

The objective of the the core requirement is to guarantee broad analytical strength for the M.S. student. To fulfill the core requirements students must take three of the following courses:

- 16.503 Solid State Physical Electronics I
- 16.507 Electromagnetics I
- 16.508 Quantum Electronics for Engineers
- 16.509 Linear Systems Analysis
- 16.513 Control Systems
- 16.515 Power Electronics
- 16.520 Computer-Aided Engineering Analysis
- 16.543 Intro. to Communication Theory
- 16.561 Computer Architecture & Design
- 16.584 Probability and Random Processes

M.S. Eng. Concentrations

The purpose of the concentration is to guarantee depth in one technical area of Electrical & Computer Engineering. A concentration is comprised of four closely related graduate courses, chosen by the student in conjunction with advice from the student's advisor and other Faculty, with the objective of furthering the student's educational objectives. It is expected that the courses comprising the

concentration will complement the work the student will undertake in fulfillment of the research requirement.

M.S. Eng. Research Requirement

The research requirement may be fulfilled by completion of an M.S. Thesis, including registration for six credits of 16.743/746 - M.S. Thesis Research, oral defense of the thesis and submission of the written document. Alternatively, the student may complete an M.S. Project, including registration for the course 16.733 - Advanced Project, oral defense, and submission of the written document. If the student chooses not to pursue the M.S. project, he or she may instead elect to complete the three credit research review course - 16.699.

M.S. Eng. Credit Requirements

Besides the M.S. Thesis (6 credits), students in the thesis track must complete an additional 24 credits of acceptable graduate-level course work. These generally will include 9 core credits, 9 concentration credits, and 6 credits of acceptable graduate electives.

A student who completes 16.733 - Advanced Project (3 credits) or 16.699 - Review of E.C.E. (3 credits) additionally must complete 30 credits of acceptable graduate-level work. These generally will include 9 core credits, 12 concentration credits, and 9 credits of acceptable graduate electives.

Opto-Electronics Option

The Opto-Electronics Option is offered in cooperation with the Department of Physics, and may be pursued by students enrolled in the M.S. Eng. program in Electrical Engineering. This option contains required and recommended courses designed to provide a fundamental background in optical devices and systems, as well as in optical physics and in the electro-optical properties of materials. A student may specialize in subjects that focus on one of three areas:

- Application of optics in telecommunication processing
- Electrooptic phenomena and laser physics
- Fabrication and analysis of new electrooptic materials

In addition to the core courses, students pursuing this option must take 16.568 - Electrooptic Systems, and at least two of the following courses: 16.508, 16.518, 16.532, 16.535, 16.583, 16.603, 16.607, 16.608, 16.610, 80.547, 80.539, 80.540, 80.551, 80.631, 95.631.

Students electing this option are encouraged to pursue M.S. Thesis research. Active areas of research include optical information processing and computing at the component and system level.

M.S. Eng. in Computer Engineering Requirements

The degree has three required core courses listed below. Areas of concentration include Chip Design, and Communication Networking; additional concentration areas can be developed by selecting an appropriate sequence of relevant ECE and/or CS courses see the list of Electives below as a guide. The Concentration, Research, and Credit Requirements for this degree are the same as for the M.S. Eng. in Electrical Engineering degree (see above).

Computer Engineering Core Courses

16.502 VLSI Design
16.561 Computer Architecture & Design
16.574 Advanced Logic Design

Chip Design Concentration

16.504 VLSI Fabrication
16.602 VHDL-Based Digital Design
plus two additional related courses

Communication Networking Concentration

16.617 Modeling & Simulation Techniques for Communication Networks
16.661 Computer & Local Area Networking
plus two additional related courses

Examples of Electives

16.508 Quantum Electronics
16.517 Real Time DSP
16.543 Intro. to Communication Theory
16.563 System Programming
16.582 Wireless Communications
16.584 Probability & Random Processes
16.664 Parallel Processing
16.665 Digital Function Analysis
16.674 Digital Processor Design
16.675 Advanced Digital Devices
16.676 Digital Design Laboratory
91.500 Fundamental Models
91.502 Foundations of Computer Science
91.563 Data Communications I

plus all other relevant ECE, CS, and Math graduate courses.

DOCTOR OF ENGINEERING PROGRAM

Objective

The primary goal of the Doctor of Engineering Program is to develop research engineers with the ability to produce new engineering knowledge. A secondary goal is to develop in them an appreciation for the social and economic issues connected with the operation of a modern high technology enterprise. The program includes advanced graduate coursework in electrical engineering and allied subjects, a non-technical component, and research culminating in a doctoral dissertation. The Doctor of Engineering degree requires completion of 63 semester hours of academic credit beyond the Bachelor of Science degree. A typical program consists of the following:

Electrical Engineering Advanced Courses and Seminar	33 credits
Management/Non-technical Component	9 credits
Doctoral Research Dissertation	21 credits
Total	63 credits

Admission Requirements

In addition to the requirements listed on page 15 in this catalog, applicants must have a B.S. or M.S. degree in Electrical Engineering or its equivalent from a recognized college or university with an acceptable quality of prior academic work. Applicants must submit official transcripts of all prior undergraduate and graduate courses. Each applicant must submit an official report of Graduate Record Examination scores for verbal, quantitative, and analytical examinations. The TOEFL exam is required for students from abroad whose native language is not English.

Transfer Credit

Up to 24 semester credits in graduate engineering courses are transferrable to the doctoral program upon approval by the ECE Department's Doctor of Engineering Committee.

Electrical Engineering Core Requirement

The core courses are the beginning graduate courses of the five areas of research

activity in the department. They emphasize the fundamentals, concepts and analytical techniques relevant to electrical engineering. They also help the student prepare for Part B of the qualifying examination. To fulfill the Core requirements students must take a minimum of three of the following courses:

16.503 Solid State Physical Electronics
16.507 Electromagnetics I
16.508 Quantum Electronics for Engineers
16.509 Linear Systems Analysis
16.513 Control Systems
16.515 Power Electronics
16.520 Computer-Aided Engineering Analysis
16.543 Intro to Communication Theory
16.561 Computer Architecture & Design
16.584 Probability and Random Processes

Doctor of Engineering Concentrations

The purpose of the concentration is to guarantee depth in one technical area of Electrical Engineering. A concentration is comprised of four closely related graduate courses, chosen by the student in conjunction with advice from the student's advisor and other Faculty, with the objective of furthering the student's educational objectives. It is expected that the courses comprising the concentration will complement the work the student will undertake in fulfillment of the research requirement.

Research Requirement and Dissertation

Each student is required to do research internship of at least one year's duration in industry, government, or at the University. The purpose of the internship is to place the student in a realistic engineering setting in which he or she will function as a responsible engineer and carry out the research work required for the dissertation. During the internship, the student must maintain close contact with the academic advisor. A written thesis must be submitted and defended orally.

Other Requirements

One year of full-time residence is required of all students in the program. To successfully complete the program, a student must achieve a cumulative grade point average of 3.25 in all course work.

Plan of Study

Each student entering the program must develop a plan of study in consultation with his/her advisor.

Qualifying Examination

A complete description of the doctoral qualifying examination is found in the EE Department's Doctoral Student Handbook. The qualifying examination consists of one written exam. The content of it will be at the undergraduate level and it is taken early in the program. Students who are not yet in the doctoral program but are interested in applying for admission may take the qualifying exam provided they meet certain requirements.

Dissertation Proposal

Having passed the qualifying exam, the student may submit his or her dissertation proposal and defend the proposal before the Doctoral Committee. Upon approval, the student's name will be submitted to the Dean of the Graduate School for acceptance as a candidate for the Doctor of Engineering Degree. Admission to candidacy status does not guarantee the obtaining of the degree.

Program Duration

The time for graduation for full-time students is expected to range from a minimum of 3 1/2 years to a maximum of 5 years after the B.S., and from 2 1/2 to 4 years after the M.S.

Doctoral Student Handbook

Further details regarding the doctoral program are listed in the Department of Electrical & Computer Engineering Doctoral Student Handbook which is updated annually.

COURSE DESCRIPTIONS

16.500 Comprehensive Study in ECE (3-0)3 This course is designed to help those students who have been out of academia for a while and who are preparing for the doctoral qualifying examination.

16.501 Discrete Algebras (3-0)3 A comprehensive course addressing the diversity of discrete algebraic systems needed in digital system synthesis and analysis. Review of sets, mappings, functions and relations. Abstract algebraic systems including lattices, groups, rings and discrete fields. Combinatorial analysis, event space algebra, solution of differential equations, discrete limits and complexity functions, elementary discrete and concrete functions. Prerequisites: Calculus and Laplace Transforms.

16.502 VLSI Design (3-0)3 Introduction to CMOS circuits including transmission gate, inverter, NAND, NOR gates, MUXEs, latches and registers. MOS transistor theory including threshold voltage and design equations. CMOS inverterís DC and AC characteristics along with noise margins. Circuit characterization and performance estimation including resistance, capacitance, routing capacitance, multiple conductor capacitance, distributed RC capacitance, multiple conductor capacitance, distributed RC capacitance, switching characteristics incorporating analytic delay models, transistor sizing and power dissipation. CMOS circuit and logic design including fan-in, fan-out, gate delsys, logic gate layout incorporating standard cell design, gate array layout, and single as well as two-phase clocking. CMOS test methodologies including stuck-at-0, stuck-at-1, fault models, fault coverage, ATPG, fault grading and simulation including scan-based and self-test techniques with signature analysis. A project of modest complexity would be designed to be fabricated at MOSIS. Prerequisite: 16.265 and 16.365.

16.503 Solid-State Physical Electronics I (3-0)3 The electronic structure of the atom, wave-particle duality of moving electrons. Schrodinger equation for periodic crystalline structure. Band theory of semiconductors. Brillouin zones. Statistics of electrons and holes. Kinetic effects: electrical conductivity, Hall effect, magnetoresistance. Optical properties: photoconductivity, light absorption and emission. Thermal properties including thermal conductivity, thermo EMF, recombination processes and role of defects. Prerequisite: 16.365 or consent of the instructor.

16.504 VLSI Fabrication (3-0)3 Fabrication of resistors, capacitors, p-n junction and Schottky barrier diodes, BJT's, MOS devices and integrated circuits. Topics include: Silicon structure, wafer preparation, sequential techniques in micro-electronic processing, testing and packaging, yield and clean room environments. MOS structures, crystal defects, Fick's laws of diffusion; oxidation of silicon, photolithography including photoresist, development and stripping. Metallization for conductors, Ion implantation for depletion mode and CMOS transistors for better yield speed, low power dissipation and reliability. Students will fabricate circuits using the DSIPL Laboratory. Prerequisite: 16.365.

16.505 Microwave Electronics (3-0)3 Review of EM theory and PN junctions. Varactors and step-recovery diode multipliers. Microwave transistors. Tunnel diodes. FET's. Transferred Electron devices - the Gunn diode. Avalanche diodes - IMPATT, TRAPATT AND BARITT diodes. Quantum electronics solid state sources - ruby masers and semiconductor lasers. Parametric and IR

devices. Prerequisite: 16.365, 16.461.

16.506 Antenna Theory and Design (3-0)3 Introduction of the fundamental principles of antenna theory: analysis, synthesis and design. Antenna parameters. Electromagnetic fields due to prescribed sources; near and far regions; reciprocity. Infinitesimal dipole. Arrays, patterns, mutual coupling. Array synthesis. Linear wire dipole, loop, traveling wave, frequency independent, aperture and horn antennas. Prerequisite: 16.461 or permission of instructor.

16.507 Electromagnetics (3-0)3 Maxwellís equations and boundary conditions. Electric and magnetic potentials. Static approximations, boundary value problems and solutions by separation of variable technique. Plane waves, dispersion, polarization, reflection and refraction. Guided waves, transmission lines and wave-guides. Cavity resonators. Optical applications. Prerequisite: 16.461.

16.508 Quantum Electronics for Engineers (3-0)3 Introduction to the fundamental postulates of quantum theory: Planck's quantization hypothesis; wave-particle duality; time-dependent & time-independent Schrodinger's Equation; simple quantum mechanical systems. Radiation and quanta; quantization of the radiation field and cavity modes; absorption and emission of radiation; coherence functions; coherent states; importance of quantum fluctuations and quantum nature of light; laser amplifiers and amplifier nonlinearity; electromagnetics and quantum theory of laser oscillators; photons in semiconductors; semiconductor photon sources and detectors.

16.509 Linear Systems Analysis (3-0)3 Correlation and Circular convolutions. Concepts of orthogonality and Grann-Schmidt orthogonetization procedure. Fourier series and Fourier transforms (FT): convergence properties; applications to linear systems including modulation, sampling and filtering. Hilbert transforms (HT) and analytic signals. Bilateral Laplace transforms (LT): convergence properties. Contour integration methods applied to FT, HT and LT. Discrete-time Fourier series and Fourier transforms including complex convolution: applications to linear systems. Discrete Fourier Transforms and Fast Fourier algorithm. Z-transforms: convergence properties, solution of difference equations, application to linear systems. Correlation. Prerequisite: 16.362.

16.510 Digital Signal Processing (3-0)3 Review of Z-Transforms and solution of linear difference equations. Digital filter structures, parameter quantization effects and design techniques. FFT and Chirp Z - Transform methods. Discrete Hilbert Transforms, minimum-phase sequences and their application to Homomorphic Signal Processing and calculation of Complex Cepstrum. Prerequisite: 16.509.

16.511 Digital Image Processing (3-0)3 Introduction to the analytical principles and methods of image representation and image processing; a series of computer projects that demonstrate these principles. Image sampling, image transforms, image enhancement and image data compression techniques; implementation of image processing algorithms based on fractal image models. Prerequisite: 16.509 or 16.510.

16.512 Electronic Materials I (3-0)3 Introduction to types of electronic materials, including semiconducting, optical, superconducting, and magnetic materials. Material quality vs. device performance. Defects such as point defects, dislocations, phase boundaries, and second phases, and their electronic effects. The phase rule, phase diagrams, and thermodynamics. Introduction to crytallography. Physical basis for quantum behavior in solid state devices. Bulk and thin film materials preparation - starting materials, crystal growth, and control requirements. Each student will undertake an individual project reviewing preparation methods for a material of industrial or research importance.

16.513 Control Systems (3-0)3 System representations, state variables, transfer functions, controllability and observability, phase variables, canonical variables, representation of nonlinear systems, Lagrangeís equations, generalized co-ordinates, time response of linear systems, state transition matrix, Sylvesterís expansion theorem, stability and state function of Liapunov, transient behavior estimation, optimal control, state function of Pontyagin, variational calculus, Hamilton Jacobi method, matrix Riccati equation, linear system synthesis. Prerequisites: 16.413.

16.514 Power Systems Analysis (3-0)3 An intermediate course in alalysis and operation of electrical power systems using mathematical techniques including applied calculus and matrix algebra. Topics include network reductions and representation of lines, generators, and transformers, network topology and transform methods. An introduction to protection and relaying is included. Symmetrical components will be introduced with application to polyphase systems. Prerequisite: 16.355.

16.515 Power Electronics (3-0)3 Design and performance analysis of rectifiers, inverters, DC chopper, AC voltage controllers, cycloconverters, and power supplies. The course includes a design project in the laboratory. Prerequisites: 16.355 and 16.366.

16.516 Advanced Machine Theory (3-0)3 Electromechanical energy conversion. Reference-frame theory. Dynamics of DC, induction, and synchronous machines. Unbalanced operation of induction and synchronous machines. Prerequisites: 16.355 and 16.366.

16.517 MMIC Design and Fabrication (3-0)3 Introduction to GaAs MMIC processes including basic FET steps, VPIN diodes, MESFET processes, via holes and ohm contacts. Design considerations including yield, die size, process tolerances, line width precision, cycle time, reticle layout, interconnect, die attach, testing and assembly. Layout rules including cell library, CAD formats, metal interconnects, bond wire, DC probe and RF probe pads, capacitors, rectangular inductors contact rules, alignment markers, scribe and saw pass indicators. RF test capabilities, including biasing, test constraints, design for test ability, layout, DC bias and ground pad requirements. FETs including small signal analysis, extrinsic networks, source inductance, models for gate periphery and material thickness. Power FETs including temperature dependent models and nonlinear models. MESFET switches including calculations for bias and maximum power, gate bias resistor and common switch configurations, Schottky planar diodes, PIN diodes, passive elements including metal interconnects, transmission lines, airbridges, microstrips, RF coupling and reliability issues. Thermal resistance, stability, biasing, losses and feedback effects. Design for manufacturability, including calculations on circuit sensitivity, process variatins, Monte Carlo yield, and electrical parameters. Power amplifiers, including design analysis, maximum power bias and load, and power delivered to the load. Active and passive mixers including theory of single-gate FET and dual gate FET. Balanced mixers including basic structures, hybrids, double balanced passive mixer, double balanced FET mixer and measurements.

16.518 Electromagnetics of Materials for Optical Engineerng (3-0) Part A: Metal Optics; Interaction of light with metal surgaces and excitation of longitudinal plasma waves inside the metal; Hydrodynamic approximation and waves in a warm plasma; Boundary conditions at a free surface; Boundary conditions at an interface between two metals of different electron densities; Reflection, transmission and resonances in thin metal films; The surface plasmon dispersion; Electrorelectance spectra at silver surfaces; Ellipsometery from metal surfaces; Resonances in small metal spheres. Part B: Dielectric Optics; Origins of light/electromagnetic scattering in dielectrics; Validity of (Kramers Kronig) dispersion relations for dielectric permittivity; the theory of dielectrics and anisotropic media; Foundations of the macroscopic electromagnetic theory of dielectrics; Optical susceptibility (linear and nonlinear); Physical origin of nonlinear permittivities, including quantum confinement effects in nanostructures; Wave mixing and harmonic generation; Electrostriction and radiation pressure; Artificial linear and nonlinear media; Speed/power trade-offs in dielectric responses.

16.519 Engineering of Submicron Machines (3-0)3 Recently fabrication of Very Large Scale Integrated circuits has spun-

off a new technology of micro-machines (MEMS) and sensors on a semiconductor wafer. These new devices are ideally located next to a microprocessor on the same wafer or a separate chip. The data transfer to and from a miniature machine, sensor or transducer is processed and controlled on site. The challenging technology of micromachine design and fabrication is described in the following way: design of mechanical, electrical and biological transducers; properties of electronic materials; pattern generation on a semiconductor wafer; interface of a micromachine and processor; applications and markets for submicron machines.

16.520 Computer-Aided Engineering Analysis (3-0)3 Taylor series. Number systems and error. Difference and summation calculus. Interpolation. Definite integrals Differential equation modeling and stability; Predictor-Corrector and Runge-Dutta methods. Orthogonal polynomials. Discrete transforms. Roots of polynomials. Zeros and stationary points of single variable functions. Gradient, quasi-Newton and conjugate gradient methods of optimization. Prerequisite: 92.234.

16.521 Real-time Digital Signal Processing (3-0)3 This course provides an introduction to real-time digital signal processing techniques using the TMS320C3x floating point and TMS320C5x fixed point processors. The architecture, instruction set and software development tools for these processors are studied via a series of C and assembly language computer projects where real time adaptive filters, modems, digital control systems and speech recognition systems are implemented. Preqs are C and/or assembly language and 16.510 or an equivalent course in one-dimensional signal processing that included discrete Fourier analysis techniques, random discrete signals and cepstral analysis techniques.

16.522 Data Structures (3-0)3 Character strings, character substring searches; lists, their storage structures and uses; trees, tree searches, and storage concepts; compiling, Polish strings, translating from infix to postfix and prefix, conversion to machine code. Prerequisite: FORTRAN and Pascal or instructor's permission.

16.528 Alternate Energy Sources (3-0)3 Photovoltaics: PV conversion, cell efficiency, cell response, systems and applications. Wind Energy conversion systems: Wind and its characteristics; aerodynamic theory of windmills; wind turbines and generators; wind farms; siting of windmills. Other alternative energy sources: Tidal energy, wave energy, ocean thermal energy conversion, geothermal energy, solar thermal power, satellite power, biofuels. Energy storage: Batteries, fuel cells, hydro pump storage, flywheels, compressed air. Course also is listed as 24.528.

16.529 Electric Vehicle Technology (3-0)3 Electric vehicles (Evs) vs. internal compustion engine vehicles. Electric vehicles and the environment. Design and analysis of electric vehicles. EV motors and controllers, batteries, battery chargers and charging algorithms, thermal management systems, and instrumentation. Hybrid Evs. Fuel cell Evs.

16.532 Computational Electromagnetics (3-0)3 Formulation of electromagnetic problems for computer solution. Variational principles in electromagnetics. Method of moments. Applications in electrostatics, wire antennas, waveguides and cavities. Simple scattering problems. Finite difference methods. Finite element method. Prerequisite: 16.461.

16.533 Microwave Engineering (3-0)3 TEM and Quasi-TEM transmission lines. Strip, microstrip, slot and coplanar lines. Rectangular and circular wavequides. Dielectric image line. Micro-wave circuit theory. Z,Y, scattering and ABCD parameters. Passive components. Ferrites. Microwave measurement techniques. Prerequisite: 16.461.

16.543 Introduction to Communication Theory (3-0)3 Information transmission and deterministic signals in time and frequency domains. Relationship between correlation and power or energy spectra. Statistical properties of noise. Spectral analysis and design of AM, FM and pulse modulation systems, continuous and discrete. AM, FM, and various pulse modulation methods, in the presence of noise. Digital modulation and demodulation techniques. Prerequisites: 16.362, 16.363 or 16.584 or equivalent.

16.544 Theory of Communication II (3-0)3 This course presents advanced topics in modern communication not covered in other courses. It is oriented towards applied modern digital communication and telecommunications. Topics include: Convolutional Coding and Decoding using the Viterbi Algorithm. Trellis code modulation for bandwidth and signal limited channels. Ungerbock set partitioning, Spread Spectrum and applications to personal communication systems, Discrete Multii-tone modulation for dispersive channels, DSP based implementation of advanced modulation, Characterization of communication channels and design of signals. Prerequisite: 16.543 or Permission of Instructor.

16.545 Coding Theory (3-0)3 Concepts and recent developments in the use of codes for error control in data handling systems. Encoding and decoding procedures and their implementation in computational algorithms and hardware organizations are investigated in detail. Prerequisite: Permission of Instructor.

16.548 Information Theory (3-0)3 Probabilistic measure of information. Determination of the information handling capacity of communication channels and fundamental coding theorems. Introduction to information coding and error correcting codes. Prerequisites: 16.471, 92.386 or equivalent.

16.549 Introduction to Intelligent Transportation Systems (3-0)3 Introduction to the technologies collectively known as intelligent transportation systems, including communications, controls, navigation and computer applications, safety and collision avoidance, and transmission media from acoustic waves to microwaves. The course covers prospects for future development of ITS and discusses systems engineering and technical experience needed to design national transportation system architectures. The course explores new cooperative and interactive approaches among engineers and vehicle manufacturers to solve technical problems posed by implementing ITS. It includes discussion of ITS America, the historic background of transportation, public and private transportation issues, technical and traffic management issues, and areas of product development and applications, particularly for defense contractors. It will give managers technical vocabulary enabling them to make informed choices on managing education in the field. Included is discussion of career areas involving ITS. An engineering or technical background would be useful for maximum benefit from the course.

16.555 Applications of Microwaves and Lasers in Medicine (3-0)3 Microwave hyperthermia, implantable radiators and techniques; EM techniques for medical diagnostics: lung water measurement, blood flow measurements, arterial wall movement by microwave Doppler radar, microwave radiometry and its uses in breast cancer; RF-field interactions with biological systems: electrical properties and biophysical mechanisms; introduction to medical optics and lasers: laser characteristics, laser surgery, optical fiber delivery systems, endoscopes, optical fiber sensors and spectrometers, phototherapy, photon migration and imaging through tissue, coherence tomography, biometrics, opthalmic applications, laser tweezers.

16.561 Computer Architecture and Design (3-0)3 Structure of computers, past and present: first, second, third and fourth generation. Combinatorial and sequential circuits. Programmable logic arrays. Processor design: information formats, instruction formats, arithmetic operations and parallel processing. Hardwired and microprogramed control units. Virtual, sequential and cache memories. Input-output systems, communication and bus control. Multiple CPU systems. Prerequisites: 16.217, 16.265.

16.563 System Programming (3-0)3 System programming structures with emphasis on re-entrant programming and pure procedures. Nested calls, push-down stacks and queues. Re-entrant interrupt programming, activation records and program sharing. Memory allocation by absolute and relocatable loaders. Macro languages, processes and assemblers. Prerequisite: 16.217.

16.565 Analog Devices & Techniques (3-0)3 A survey of analog devices and techniques, concentrating on operational amplifier

design and applications. Operational amplifier design is studied to reveal the limitations of real op-amps, and to develop a basis for interpreting their specifications. Representative applications are covered, including: simple amplifiers, differential and instrumentation amplifiers, summers, integrators, active filters, nonlinear circuits, and waveform gene-ration circuits. A design project is required. Prerequisite: 16.366

16.568 Electrooptics & Fiber Optics (3-0)3 Introduction to optoelectronics and laser safety; geometrical optics; waves and polarization; Fourier optics; coherence of light and holograpy; properties of optical fibers; acousto-optic and electro-optic modulation; elementary quantum concepts and photon emission processes; optical resonators; Fabry Perot etalon; laser theory and types; review of semiconductor lasers and detectors; nonlinear optics. Prerequisite: 16.360.

16.569 Electrooptics and Infrared Systems (3-0)3 Introduction to optoelectronics and laser safety; ir sources and blackbodies, characterization of sources, ir signatures and camouflage, geometrical optics; waves and polarization; optical alignement techniques, diffraction, Fourier optics; coherence of light; elementary quantum concepts and photon emission processes; optical resonators; laser theory and types; review of semiconductor lasers and detectors; optical design for ir imaging, testing ir systems, focal plane arrays. Prerequisite: 16.360.

16.570 Solar Cells - Design, Technology and Applications (3-0)3 Economy of solar cell energy conversion, electrical and optical properties of semiconductors, operation of pn junction, design of solar cells and solar cell manufacturing. Solar cells for individual customers, utility networks, the military and space. Mid term design project and laboratory measurments required.

16.571 Radar Systems (3-0)3 Introduction to both pulsed and C.W. radar systems. Detection of radar echoes in noise. The radar equation and its use in estimating performance of a radar system. Estimation of range, direction and velocity of targets. Moving target indicators (MTI). Pulse compression and other advanced techniques. Discussion of elements of practical radar systems. Prerequisite: 16.461.

16.574 Advance Logic Design (3-0)3 Geometric representation of binary numbers. Switch networks. Reed-Muller polynomials. Minimization by Quine-McCluskey (tabular) method. Transient analysis of hazards and hazard-free design. Special properties of switching algebra: symmetric functions, unate functions, threshold functions, Boolean difference and decomposition. Analysis of fundamental-mode and pulse-mode sequential circuits. Sequential circuit synthesis. Programmable logic devices. Test sets and design for testability. Prerequisites: 16.217, 16.265, 16.365.

16.575 FPGA Logic Design Techniques (3-0)3 Advanced logic design techniques using field programmable gate arrays (FPGAs), programmable logic devices, programmable array logic devices, and other forms of reconfigurable logic. Architectural descriptions and design flow will be covered as well as rapid prototyping techniques, ASIC conversions, in-system programmability, high level language design techniques, and case studies highlighting the tradeoffs involved in designing digital systems with programmable devices. This course is generally offered summers only. Prerequisites - Digital Logic Design or Equivalent.

16.582 Wireless Communications (3-0)3 Study of radio wave propagation. Factors affecting the performance of terrestrial line-of-sight microwave radio systems and cellular mobile radio systems. Design and field operation of QAM digital radio systems. Computation of statistics of system performance including availability and errors. Prerequisite: 16.461.

16.583 Wave Propagation in Plasmas (3-0)3 Plasma waves and the interaction of electromagnetic radiation with plasmas, specifically the earth's ionosphere. Refraction, reflection, dispersion, absorption, and ray paths. Ionospheric effects on ground-to-ground and ground-to-satellite radio and over-the-horizon radar systems. Review of ionospheric physics. Prerequisite: 16.461.

16.584 Probability and Random Processes (3-0)3 Sample space, Field and Probability Measure. Axiomatic definition of Probability. Bayes' theorem. Repeated trials. Continuous and discrete random variables and their probability distribution and density functions. Functions of random variables and their distribution and density functions. Expectation, variance and higher order moments. Characteristics and generating functions. Vector formulation or random variables and their parameters. Mean square estimation and orthogonality principle. Criteria for estimators. Introduction to random processes: distribution and density functions; Ensemble and time averages; correlation functions and spectral densities. Classification of random processes. Random processes through linear systems. Weiner filters and Kalman filters. Co-requisite: 16.509. Prerequisite: 16.362.

16.590 Fiber Optic Comunications & Networks (3-0)3 Optical fiber; waveguide modes, multimode vs single mode; bandwidth and data rates; fiber losses; splices, couplers, connectors, taps and gratings; optical transmitters; optical receivers; high speed opto-electronic devices; optical link design; broadband switching; single wavelength systems (FDDI, SONET, ATM); coherent transmission; wavelength division multiplexing and CDMA; fiber amplifiers. Prerequisites: 16.360, 16.362 or permission of instructor.

16.602 VHDL-based Digital Design (3-0)3 Circuit and system representations including behavioral, structural, and physical descriptions using HDL. Modeling of short and narrow MOS transistors for submission applications. Overview of CMOS technology including oxidation, epitaxy, deposition, ion implantation and diffusion essential for multilayer vias. 2-0 and 4-0 memory structures, I/O structures and PADS. System design including structural, hierarchy, regularity, modularity and programmable gate arrays. RTL snythesis, layout and placement, design capture tools, including schematic, netlist, verification and simulation. Fast adders, subtractors, multipliers, dividers, ALUs, CPUs, RAMs, ROMs, row/column decoders, FIFOS, and FSMs with detailed examples. A RISC microcontroller, pipeline architecture including logic blocks, data paths, floor planning, functional verification and testing. Layout and simulation of chips as well as of PCs based on VHDL, verilog, and HILO will be encouraged. A project of industrial vigor for fabrication at MOSIS is required. Prerequisite: 16.502

16.603 Solid State Physical Electronics II (3-0)3 Topics included are physical limits of microminiaturization, metal semiconductor junctions, p-n junctions diodes, (rectifiers, varactors, tunnel diodes and photodetectors and solar cells); bipolar junction transistors, field effect transistors (junction FET, MESFET, MOSFET); heterojunction devices and high speed devices; quantum dots, wires and two dimensional quantum well devices, light emitting devices; flat panels, liquid crystals and hot electron emitters. Prerequisite: 16.503.

16.605 Defects in Semiconductor Device Technology (3-0)3 Thermodynamics of defect generation, mechanisms of their interaction and movement. The generation of point defects, dislocations, two dimensional defects specifically during every technological step, such as wafering, oxidation, diffusion, epitaxy, etc. Influence of dislocations and point defects on electrical and optical properties of silicon and compound semiconductor devices. Techniques for reduction of defects in device fabrication technology. Prerequisite: Permission of Instructor.

16.606 High Speed Semiconductor Devices (3-0)3 Materials technologies for high speed devices, ideal semiconductors and fabrication technologies; electric field and current transport, electrons in strong electric field, tunneling, space charge limited current, hot electrons, shape of field in channel; device building blocks, symmetric n-i-n structure, inversion layers, quantum wells. The following devices will be described: submicron MOSFETs, SOI-MOSFETs, short channel MESFETs, the permeable base transistor, heterojunction transistors, single electron transistor and high speed photonic devices.

16.607 Electromagnetics of Complex

Media (3-0)3 Electromagnetic wave interactions with complex media are the basis of many modern emerging technologies in optical, plasma and microwave engineering. Wave propagation in chiral, magnetoplasma, ferrite, moving, time-varying, inhomogeneous and periodic media. Surface waves. Prerequisite: 16.507.

16.608 Scattering and Diffraction of EM Waves (3-0)3 Review of EM Theory. Scattering from a long cylinder for TM and TE waves. Scattering pattern and cross section. Scattering from a sphere. Rayleigh and Mie regions. Half-plane and wedge diffraction. GTD and applications for high frequency scattering. Babinet's principle and diffraction by an aperture. Physical theory of diffraction. Weiner-Hopf methods. Prerequisite: 16.507.

16.609 Measurements of Semiconductor Materials and Device Parameters (3-0)3 This course covers new emerging technology of nondestructive measurements in the quality control of both semiconductor wafers and semiconductor devices. The emphasis is on the physics and electronics of the new methods and their limitations. Some laboratory measurements are included with the course to let students acquire experimental skills in testing and measurements; these include eletrical measurements, optical measurements, optical and electron microscopy.

16.610 Optics for Information Processing (3-0)3 Rigorous treatment of diffraction theory and Fourier optics; Coherence theory and interferometry; Analog Fourier computing; Holographic filters; Nonlinear optical phenomena; Spatial light modulation; Photorefractive memories and phase conjugation; Digital optical processors and optical interconnects; Optical neural networks; Current and future trends in optical computing. Prerequisite: Permission of instructor.

16.613 Nonlinear Systems Analysis (3-0)3 Roots of polynomials. Zeros and stationary points of single variable functions. Gradient, Quasi-Newton and conjugate gradient methods of constrained optimization. Approximation methods for ordinary and partial non-linear differential equations. Stability and the methods of Lyapunov. Prerequisite: 16.520.

16.614 Optimal Control Theory (3-0)3 Deterministic optimal control systems. Performance measures for optimal systems. Dynamic programming and related computer techniques. Discrete linear regulator. The Hamilton-Jacobi-Bellman equation. Continuous linear regulator. Calculus of variations and Pontryagin's minimum principle. Minimum time problems. Minimum effort problems. Prerequisites: 16.509 and 16.513.

16.615 Solid State Drive Systems (3-0)3 Elements of variable speed drive systems. Rectifier and chopper control of DC drives. Control of induction motors by AC voltage controllers. Frequency-controlled induction motor drives. Slip-power controlled wound-rotor induction motor drives. Synchronous motor speed control. Prerequisite: 16.515.

16.616 Computational Methods in Power System Analysis (3-0)3 Power system matrics, power flow studies, fault studies, state estimation, optimal power dispatch, and stability studies. Prerequisites: 16.443 and 16.520.

16.617 Modeling and Simulation Techniques for Communication Networks (3-0)3 Overview of general architectures for B-ISDN and Internet, network layering, signalling, performance requirements, traffic management strategies, usage parameter control, connection admission control, congestion control, stochastic processes, Markov chains and processes, stochastic models for voice, video and data traffic, Poisson processes, Markov-modulated processes, traffic analysis, queueing systems, M/M/1, M/M/m, M/G/1 queues, fluid buffer models, effective bandwidth approaches, simulation modeling, discrete event simulation of transport and multiplexing protocols using OPNET software, statistical techniques for validation and sensitivity analysis.

16.619 Digital Control Systems (3-0)3 Discrete-time systems. Sampling and reconstruction of signals. Z-transform, sampled data systems, digital filters, design using transform techniques, design using state-space methods, multivariable and optimal control, quantization effects and sample rate selection, nonlinear control. Introduction to Kalman filters. Prerequisites: 16.510 and 16.513.

16.661 Computer and Local Area Networking (3-0)3 Characteristics and topology of Local Area Networks (LANs), WANS and MANs. Design of cable plants based on co-axial as well as fiber optic technologies. Data communication including transmission, reception, bandwidth, error correction and detection. Data flow in networks and queuing theory. G/M/1 model and M/D/1 model and priority. Circuit switched networks including data switches, blocking analysis, sizing of PBXs. Network structures, access techniques and performance measures. Access protocols including ALOHA, slotted ALOHA and CSMA/CD. Central control and basic capacity. Polling networks including their analysis, delay and performance. Topologies such as star, ring, bus and basic operations based on token rings and slotted rings. Random access networks and their analysis pertaining to CSMA/CD, slotted ALOHA, content and congestion control. Prerequisite: 16.561 or 16.563.

16.664 Parallel Processing (3-0)3 Supercomputer organization, architectures and application algorithms. Multiple pipeline, bus, and switch based multiple processor systems. Multi-level cache and multi-dimensional access memory structures. Neural network models and implementations. Current research and production parallel processing computers. Prerequisite: 16.563 and 16.561.

16.665 Digital Function Analysis (3-0)3 Theoretical aspects of digital systems from a mathematical perspective. The theories of switching, automata and formal languages are developed as the basis for the discussion of the theories of computability and computational complexity. Extensive analysis is given to the most common functions that occur in digital systems including arithmetic and controller structures. Prerequisites: 16.501, 16.414 or 16.574.

16.667 Operating Systems Students should register for 91.588.

16.671 Advanced Computer Architecture (3-0)3 Architectural analysis of high performance single processor and systolic processor systems. Memory structure optimization, pipeline control and high-speed arithmetic structures. Cost and performance of switch-based multiple processor systems. Analysis of alternative architectures including associative array and data flow machines. Prerequisite: 16.561.

16.674 Digital Processor Design (3-0)3 Algorithms at the register transfer level; cost and performance tradeoffs with decomposition and optimization. Design of complex digital structures using large scale integrated and semi-custom devices. Detailed timing analysis of processor interface busses and memory subsystems. Use of special purpose microprocessors to realize digital systems. Prerequisite: 16.574.

16.675 Advanced Digital Devices (3-0)3 State of the art microprocessors are examined and compared to their eight bit counterparts. The four architectional concepts of memory segmentation, operated addressing structure, operation register set, and instruction encoding scheme are evaluated for different families of processor design. Arithmetic and logical instruction support for high performance numeric processing requirements are discussed using numeric data processors. Prerequisite: 16.674.

16.676 Digital Design Laboratory (2-3)3 Brief introduction to C. Application of digital devices and systems to realistic engineering problems. Design, development, construction, and testing of systems emphasizing state-of-the-art digital design methodologies. Enrollment limited; extensive time in laboratory required. Prerequisite: 16.674.

16.684 Time Series Analysis & Forecasting With Applications (3-0)3 Review of Estimation of Stochastic processes: Estimation of mean, variance, autocovariance, autocorrelation and normalized autocovariance of discrete stochastic processes; Generation of White Noise Sequences and tests for white noise; Difference operations. Linear Stationary models: Autoregressive (AR) processes, Yule-Walker equations, partial correlation. Moving Average (MA) processes, invertibility conditions and solution for MA parameters; Relation between AR and MA

processes; Autoregressive Moving Average (ARMA) processes, formulation and solution for ARMA parameters. Levinson-Durbin & related algorithms: Deterministic and Probabilistic Methods; Forward-Backward Prediction; Lattice Methods. Gram-Schmidt Orthogonalization method; Burg Algorithm. Linear nonstationary Models: Autoregressive Integrated moving Average processes, differencing to induce stationarity and determination of the order of differencing. Model Identification and Diagnostic Checking: Examples for model identification; Portmanteau test and other tests for residuals to check for white noise. forecasting: Several methods for forecasting; Box-Jenkins forecasting functions, three types; Examples for the three types of forecasting; One-step linear predictors and confidence limits. Seasonal Time Series: Formulation of seasonal time series models and basic ideas of forecasting.

16.685 Statistical Communication Theory (3-0)3
Review of probability and random variables. Random processes; statistics of white noise; Fourier analysis of periodic random processes; Karhunen-Loeve expansion; narrow-band Gaussian processes; linear systems. Discrete-time and continuous-time matched filters; spectral factorization and solution of integral equations. Maximum likelihood receivers. Digital modulation. Information theory: entropy, ratio distortion theory, channel capacity, and introduction to coding. Prerequisites: 16.509 and 16.584 or permission of instructor.

16.687 Applied Stochastic Estimation (3-0)3
Review of random processes and key elements of probability theory. State space description of systems and random processes, relation to frequency domain techniques. Numerical methods of continuous and discrete time random sytem modeling. Optimal Kalman filtering for discrete and continuous random systems. Sensitivity analysis. Design considerations in the face of model uncertain ty, numerical instabilities, bad data. Optimal smoothing. Nonlinear filtering. Parameter identification. Applications throughout. Prerequisite 16.584.

16.692 Directed Studies (3-0)3
Provides opportinity for students to get a specialized or customized course in consultation with a faculty member.

16.699 Review of Electrical & Computer Engineering (formerly "Seminar") (3-0)3
Development, preparation, and written and oral presentation of a report on an advanced engineering topic: Oral presentation of proposals; modification and redefinition as required; oral presentation to the class and instructor of results of investigation; submission of final written report. Grade based on clarity of exposition, knowledge of subject, ability to clearly and effectively answer questions, and participation in the discussion of other papers. Class size limited to ten students. Prerequisites: minimum of 15 credit hours of graduate courses: for students in the non-thesis option only. Replaces 16.700.

16.701 Graduate Research Seminar (1-0)0 Discussion and analysis of advanced research projects. Sections are available for individual concentrations. Prerequisite: Permission of instructor.

16.710/16.729 Selected Topics in Electrical Engineering (3-0)3
Advanced topics in various areas of Electrical Engineering and related fields. Prerequisite: specified at time of offering.

16.733 Advanced Graduate Project (0-6)3 The Advanced Project is a substantial investigation of a research topic under the supervision of a faculty member. A written proposal must be on file in the Electrical & Engineering Graduate Office before enrollment. A written report is required upon completion of the project. This course can be taken only once, and may evolve into a master's thesis. However, credit for this course will not be given if thesis credit is received.

16.743 Master's Thesis Research (0-6)3

16.746 Master's Thesis Research (0-12)6
Co-requisites: Minimum of 6 credit-hours of graduate courses at an acceptable level when registering for first three credits and 12 credit hours when registering for subsequent credits; matriculated status in the M.S. Eng. program in Electrical, Computer or Systems Engineering; approval of a written proposal outlining the extent and nature of proposed research work. The report on the research work, performed under the supervision of a faculty member, must be published in appropriate form and presented to a committee of three faculty members appointed at the time of acceptance of the thesis proposal. The student is required to give an oral defense of the thesis before the committee and other faculty members.

16.753 Doctoral Dissertation Research (0-6)3

16.756 Doctoral Dissertation Research (0-12)6

16.759 Doctoral Dissertation Research (0-18)9 Prerequisites: Written approval by the dissertation advisor; matriculated status in the doctoral program in E.E. No more than 9 credits of doctoral dissertation research may be taken before passing the doctoral qualifying examination. No more than 15 credits of doctoral dissertation research may be taken before passing the defense of the thesis proposal examination.

ENERGY ENGINEERING

Graduate Coordinators:
Solar Option:
John J. Duffy
Professor of Mechanical Engineering; B.S., Christian Brothers College; M.S., Illinois Institute of Technology; D.Sc., Washington University (St. Louis).

Nuclear Option:
Gilbert Brown
Professor of Nuclear Engineering; B.S., Cornell University; M.S., Ph.D., Massachusetts Institute of Technology.

Associated Faculty:
Leo Bobek
Adjunct Assistant Professor
Reactor Supervisor, B.S., M.S. University of Massachusetts Lowell.
Alfred A. Donatelli
Professor of Chemical Engineering; B.S., Lowell Technological Institute, Ph.D., Lehigh University.
Aram S. Karakashian
Professor of Physics; B.A., M.A., Temple University; Ph.D., University of Maryland.
Samson Mil'shtein
Professor of Electrical Engineering; B.S., M.S., State University of Odessa, USSR; Ph.D., University of Jerusalem.
Eugene E. Niemi, Jr.,
Professor of Mechanical Engineering; B.S., Boston University; M.S., Worcester Polytechnic Institute; Ph.D., University of Massachusetts.
Ziyad M. Salameh
Professor of Electrical Engineering; B.S., Moscow Power Engineering Institute, USSR; M.S., Ph.D., University of Michigan.
Dominick A. Sama
Professor of Chemical Engineering; S.B., S.M., Ph.D., Massachusetts Institute of Technology.
James R. Sheff
Professor of Nuclear Engineering; B.S., University of Colorado; M.S., Ph.D., University of Washington.
Changmo Sung
Associate Professor of Chemical Engineering; B.S., Seoul National University, Korea; M.S., Ohio State University; Ph.D., Lehigh University.

Fahd Wakim
Associate Professor of Electrical Engineering; B.S., American University of Beruit; M.A., Ph.D., University of Texas.
John R. White
Professor of Nuclear Engineering; B.S., University of Lowell; M.S., Ph.D., University of Tennessee.

MASTER OF SCIENCE DEGREE PROGRAM IN ENERGY ENGINEERING

The graduate programs in Solar Engineering and Nuclear Engineering offer professional training at the master's degree level designed to prepare the student to perform state-of-the-art work on energy systems. The programs are designed to achieve a balance between hands-on experience and theory. Energy engineering involves subject matter and draws students from all branches of engineering, physics, mathematics, and economics.

Thesis and Non-Thesis Requirements

Participants in the program may elect to follow a thesis or non-thesis option. The thesis option requires a minimum of 30 credit hours: 24 credit hours of course work plus six credit hours of thesis research. A thesis must be defended in an oral examination conducted by the student's thesis committee.The non-thesis option requires a minimum of 30 credit hours: 27 credit hours of course work plus three credit hours of project work (Master's Project 24.733).

Course Requirements

Each student must take a series of core courses appropriate for the area of specialization. The exact makeup of the student's curriculum will be guided and approved by the Graduate Committee of the Energy Engineering program.

All students working toward the Master of Science degree in Energy Engineering must take the following courses:

24.504 Energy Engineering Workshop
24.509 System Dynamics, and
10.528 Advanced Transport Phenomena

For the Solar Option, the following are required:

22.521 Fundamentals of Solar Thermal Utilization
22.527 Solar Systems Engineering

The following courses are required for the Nuclear Option:

24.505 Nuclear Reactor Physics
24.507 Nuclear Reactor Engineering Analysis

In addition to the course and credit requirements described above, all students working toward the M.S. degree are required to participate in the Graduate Research Seminar, 24.601/602. The remainder of the course requirements is to be made up of elective courses, approved by the appropriate graduate coordinator.

Elective Courses

The following courses have been taken as electives but choice is not restricted to these:

16.513 Control Systems
16.528 Alternative Energy Systems
16.529 Electric/Hybrid Vehicles
18.527 Energy and the Environment
18.527 Environmental Laws
18.580 Implementation of Environmental Policy
22.524 Special Topics Solar Engineering
22.543 Convective Heat and Mass Transfer
22.544 Conduction and Radiative Heat Transfer
22.573 Manufacturing Systems
22.581 Advanced Fluid Mechanics
24.506 Special Topics in Nuclear Reactor Physics
24.508 Special topics in Nuclear Reactor Engineering
24.514 Hazardous and Nuclear Waste Management
24.522 Nuclear Materials
24.529 Geothermal Energy
24.533 Windmill Applications
24.539 Math Methods for Engineers

COURSE DESCRIPTIONS

10.528 Advanced Transport Phenomena (3-0)3 Prerequisite: Permission of Instructor. An advanced study of the mechanism of momentum, heat and mass transfer. The equations of continuity, motion and energy are used to examine steady and unsteady state processes. Considerable emphasis is placed upon solutions to problems.

22.521 Solar Fundamentals (3-0) 3 Prerequisite: Permission of Instructor. Terrestrial irradiation on tilted surfaces; radiation, conduction, convection in collectors; absorptance, emittance, reflection, transmittance of solar irradiation; energy flow in flat plate and concentrator collectors; storage; design tools; small project.

22.524 Special Topics Solar Engineering (3-0)3 Prerequisite: 22.521, 22.527. Topics depend on student interest and could include overview of solar thermal and photovoltaic projects and concepts, solar crop drying, solar cooling, wave energy, stochastic process models of solar systems, design tool development, solar electric vehicles, fuel cells, electrolyzers. A project is required.

22.527 Solar Systems Engineering (3-0)3

Prerequisite: Permission of Instructor. Passive solar heating and cooling, photovoltaic, and daylighting systems design and analysis with steady-state, dynamic, and stochastic models as well as life-cycle cost/benefit analysis. Small design project.

24.504 Energy Engineering Workshop (3-0)3 Prerequisite: Permission of Instructor. A group design project. The design effort will integrate many aspects of the student's engineering background, including design concepts, technical analyses, economic and safety considerations, etc. A formal report and oral presentation are required.

24.505 Nuclear Reactor Physics (3-0)3 Prerequisite: Permission of Instructor. Advanced treatment of several topics in reactor physics, including cross sections and processing methods, development of transport theory, reduction to diffusion theory, and analyses of analytical and numerical solutions of the resultant balance equations.

24.506 Special Topics in Nuclear Reactor Physics (3-0)3 Prerequisite: Permission of Instructor. Potential topics include nodal methods, perturbation theory, transport theory methods, data sensitivity and uncertainty analysis, fuel management and core optimization methods, noise analysis, space-time kinetics, reactor control, reactor safety, etc. May be repeated since topics vary.

24.507 Nuclear Reactor Engineering and Safety Analysis (3-0)3 Prerequisite: Permission of Instructor. Modeling and analysis of reactor thermal-hydraulics and safety systems. Topics include nuclear heat generation and transport, single and two-phase flow, boiling crisis, and safety analysis.

24.508 Special Topics in Nuclear Reactor Engineering (3-0)3 Prerequisite: Permission of Instructor. This course will address topical issues in nuclear engineering such as advanced reactor designs, proliferation resistant fuel cycles, space applications, license renewal, and decommissioning.

24.509 System Dynamics (3-0)3 Prerequisite: Permission of Instructor. Mathematical foundation for systems analysis using the state-variable approach. Topics include matrix methods, Laplace transforms, transfer functions, frequency response and stability analyses, and the control of distributed and lumped parameter systems. Emphasis on modeling and simulation techniques within the MATLAB/SIMULINK package. Applications to mechanical, thermal, fluid, chemical, and general energy systems. A detailed course project is required.

24.514 Hazardous and Nuclear Waste Management (3-0)3 Prerequisite: Permission of Instructor. History of nuclear waste disposal; engineering design of disposal systems. Present status of waste and the character and quantities of future wastes. Review of disposal concepts on a generic basis. The national plan for waste disposal.

24.519 Nuclear Reactor Operator Training (0-6)3 Prerequisite: Permission of Instructor. Training, including in-reactor experience and topical lectures, as given to Reactor Operator Trainees who will undergo Federal testing for a Reactor Operator License.

24.520 Nuclear Reactor Operator Training (0-6)3 Prerequisite: Permission of Instructor. Continuation of 24.519. Upon completion of this course, the student typically will be given a simulated Reactor Operator examination, including a written test, and oral test, and a controls manipulation test.

24.522 Nuclear Materials (3-0)3 Prerequisite: Permission of Instructor. Review of metals and metal oxide properties. Radiation damage in solids, plastics, ceramics, electronics, and graphite. Hardening, embrittlement, swelling, and creep in metals. Damage mechanisms. Shielding materials.

24.529 Geothermal Energy (3-0)3 Prerequisite: Permission of Instructor. Systematic study of geothermal energy resources and their distribution. Economics of geothermal applications. One type of geothermal plant will be studied from concept through operation.

24.531/532 Directed Studies in Energy Engineering (3-0)3 Prerequisite: Permission of Instructor. Individual research projects in a variety of topics in nuclear, solar or general energy engineering and technology. Emphasis is on state-of-the-art research methods in the particular field of interest. May be repeated with consent of advisor.

24.533 Windmill Applications (3-0)3 Prerequisite: Permission of Instructor. Introduction to the theory and engineering analysis of windmills. Included is consideration of the machine and machine types, the tower, energy conversion modes, and economic analysis. Consideration is given to the state-of-the-art and existing machines and projects are reviewed.

24.539 Math Methods for Engineers (3-0)3 Prerequisite: Permission of instructor. Ordinary and partial differential equations, linear algebra, matrix/vector calculus, numerical methods, introduction to optimization methods, and other topics as time permits. Both the analytical and numerical techniques are integrated to give good analytical skills coupled with practical problems solving tools. Extensive computer work with the MATLAB package is required.

24.733 Masters' Project in Energy Engineering (3-0)3 Prerequisite: Permission of Instructor. Advanced research project required of all students electing non-or design thesis option.

24.743, 24.746, 24.749 Masters' Thesis Research (0-9,18,27)3,6,9 Prerequisite: Permission of Instructor. Advanced energy engineering research related to thesis work.

24.601/602 Graduate Research Seminar (1-0) 0 Presentation and discussion by faculty, invited speakers, and qualified graduate students of recent developments in the field of energy engineering, energy policy and the financial and social costs of power. Required for all graduate students. Weekly meetings.

MANUFACTURING ENGINEERING

The University offers two programs in manufacturing engineering:

The Master of Science in Mechanical Engineering has a concentration available in manufacturing in the Mechanical Engineering Department (see Mechanical Engineering).

The Doctor of Engineering in the Mechanical Engineering Department offers an option in manufacturing.

DEPARTMENT OF MECHANICAL ENGINEERING

Department Head

Struan R. Robertson
Professor; B.S.,M.S., Clarkson University; Ph.D., Rensselaer Polytechnic Institute.

Faculty

Majid Charmchi
Professor; B.S., Arya-Mehr University of Technology; M.S., Ph.D., University of Minnesota.

Julie Chen
Associate Professor, B.S., M.S., Ph.D., Massachusetts Institute of Technology.

John Duffy
Professor; B.S., Christian Brothers College; M.S., Illinois Institute of Technology; D.Sc., Washington University.

William T. Hogan
Professor; B.S., Northeastern University; S.M., Massachusetts Institute of Technology; Sc.D., Massachusetts Institute of Technology.

William Kyros
Professor; B.S., University of Lowell; S.M., Massachusetts Institute of Technology; Ph.D., Cornell University;
P.E.

John McKelliget
Associate Professor; B.Sc., Exeter University, U.K.; Ph.D., Sunderland Polytechnic, U.K.

Alan Mironer
Professor; B.M.E., Rensselaer Polytechnic Institute; M.Eng., Yale University; Ph.D., Syracuse University;
P.E.

Eugene E. Niemi, Jr.
Professor; B.S., Boston University; M.S., Worcester Polytechnic Institute; Ph.D., University of Massachusetts Amherst; P.E.

John C. O'Callahan
Professor; B.S., M.S., Ph.D., Northeastern University; P.E.

Robert E. Parkin
Professor; B.Sc. (Eng.), University of London; Ph.D., Imperial College, University of London; D.I.C., Imperial College.

James A. Sherwood
Associate Professor, B.S., M.S., Ph.D., University of Cincinnati, P.E.

Sammy Shina
Associate Professor; B.S., Massachusetts Institute of Technology; M.S., Tufts University; Ph.D., Worcester Polytechic Institute; P.E.

David Smith
Associate Professor; B.S., M.S., Ph.D., Georgia Institute of Technology.

Yakov M. Zilberberg
Associate Professor; M.S., Odessa Technical Institute, Ph.D., University of New Hampshire; P.E.

DEGREE PROGRAMS IN MECHANICAL ENGINEERING

The admission requirements of the University are to be followed for all degree programs in Mechanical Engineering. The student is required to submit official transcripts for all prior college level studies, official score report for the Graduate Record Examination Aptitude Test, and three letters of recommendation. Applicants for Master or Doctor of Engineering Degrees in Mechanical Engineering must be in possession of a bachelor's degree in engineering or equivalent. Mechanical Engineering graduates can also apply for the Ph.D. degree in Applied Physics.

MASTER OF SCIENCE DEGREE

The department offers an M.S. program and a B.S./M.S. program. These programs offer a choice of two options: a thesis option and a nonthesis option. To receive the M.S. degree requires a minimum of thirty-three credit hours of acceptable graduate work, including nine credit hours of research for the thesis option or nine credit hours in an acceptable minor for the nonthesis option.

The student may register for research only after submitting a thesis proposal and a thesis agreement signed by the thesis advisor to the graduate coordinator. The thesis agreement is reviewed and approved by a committee of at least three faculty members including the advisor. Upon completing the thesis, the student is required to defend it orally before the committee. The committee must be in possession of a completed version of the thesis at least 14 days before the thesis is defended.

All MS degree candidates must satisfy each of the following four core requirements:

1.
22.539 or Math Methods
92.545 Partial Differential Equations I,
or
92.530 Applied Math I,
or
22.587 Numerical Methods
(Manufacturing concentration only)
or
Other approved course in mathematics.

2.
22.562 Solid Mechanics I,
or other approved course in Mechanics

and Materials.

3.

22.581 Advanced Fluid Mechanics (required by students in Thermo/Fluids/Energy concentration), or
22.542 Convective Heat and Mass Transfer, or
22.544 Conduction and Radiative Heat Transfer.

4.

22.743/746/749 Master's Thesis or approved minor.

Students in the MS program may choose from one of four concentrations in their first semester after matriculation and must choose an advisor (for thesis in that concentration); otherwise an advisor will be assigned for them. The concentration courses that students may take are:

Mechanics & Materials Concentration
22.512 Applied Finite Element Methods
22.513 Finite Element Methods
22.562 Solid Mechanics I
22.563 Solid Mechanics II
22.591 Mechanical Behavior of Materials
22.593 Failure Analysis
22.596 Composite Materials
22.597 Composite Processing
22.614 Nonlinear Finite Element Methods
22.615 FEA of Composites
22.644 Plate Theory
22.645 Shell Theory
22.697 Structural Application of Composite Materials

The Thermo/Fluids concentration courses are:
22.581 Advanced Fluid Mechanics
22.582 Viscous Flow
22.542 Convective Heat and Mass Transfer
22.540 Conduction Heat Transfer
22.541 Radiation Heat Transfer

The Energy concentration courses are:
10.528 Advanced Transport Phenomena
22.521 Solar Fundamentals
22.527 Solar Systems Engineering
24.509 Dynamic Systems

Vibrations/Dynamics Concentration:
22.515 Modal Analysis Theoretical Methods
22.516 Experimental Modal Analysis
22.519 Dynamic Model Correlation

Manufacturing Concentration:
Coordinators: Professors Sammy Shina and Robert E. Parkin
22.571 Concurrent Engineering and Quality
22.572 Manufacturing Processes
22.573 Manufacturing Systems Engineering
22.575 Industrial Design of Experiments
22.579 Robotics

The manufacturing concentration is designed to accommodate engineers from all disciplines. The entrance requirement is a B.S. in Mechanical Engineering or other engineering discipline at an acceptable grade point average.

Students who wish to pursue an MSME with a BS degree in engineering or a physical science which is not in Mechanical Engineering may be required to take up to 5 undergraduate BSME courses in order to ensure that the student has the sufficient fundamentals to complete the MSME degree.

The Energy Engineering Program

The University offers a Master of Science degree in Energy Engineering. This unique area of concentration represents a separate multidisciplinary program that is administered jointly by the Mechanical Engineering Department and the Chemical and Nuclear Engineering Department. The Energy Engineering Program has two M.S. degree options: Solar Engineering and Nuclear Engineering. Students interested in either of these program options should refer to the catalog section focused specifically on the Energy Engineering Program.

In addition, a Doctor of Engineering degree is offered in Mechanical Engineering with options in either Nuclear Engineering or Solar Engineering, and a program leading to a Doctor of Philosophy degree in Applied Physics with an option in Energy Engineering is offered jointly by the Department of Physics and the Energy Engineering Program. For further information about either of these doctoral programs, please refer to the appropriate sections under Mechanical Engineering or Physics.

Approved Minors for the Nonthesis MSME option

The minor option associated with the nonthesis MSME is developed within a framework of a three-course sequence within a technical area outside of mechanical engineering. The following courses have been approved for application to the following minors. In addition, a student may propose a customized minor in another area.

Manufacturing Management:
63.710 Design and Control of Manufacturing Systems
63.720 Manufacturing Strategy
64.802 Quantitative Methods for Decision Evaluation
64.804 Market and Consumer Values
66.710 Managing for Competitiveness 1

Ergonomics:
19.525 Introduction to Ergonomics and Industrial Hygiene (Required)
19.531 Occupational Biomechanics
19.532 Occupational Biomechanics Laboratory
19.632 Advanced Biomechanics (pre req. 19.531)
19.638 Work Methods Analysis

Industrial Hygiene:
19.525 Introduction to Ergonomics and Industrial Hygiene (Required)
19.514 Aerosol Science
19.517 Physical Agents Evaluation
19.518 Engineering Controls and PPE
19.610 Exposure Assessment
19.613 Design and Evaluation of Ventilation Systems (prereq. 19.518)

Bioprocessing:
10.535 Principles of Cell and Microbe Cultivation
10.545 Isolation and Purification of Biotech Products
10.586 Biotechnology Processing Projects Laboratory

Materials:
10.501 Paper Industry Process Analysis
10.506 Colloid and Interfacial Science and Engineering
10.523 Electronic Materials Processing
10.525 Design and Use of Packaging Materials
10.531 Survey of Ceramic Materials
10.533 Macromolecular Science and Engineering

Solar Energy:
22.521 Fundamentals of Solar Energy
22.527 Solar Energy Engineering
24.504 Energy Engineering Workshop
24.509 Dynamic Systems Analysis

Nuclear Energy:
24.505 Reactor Physics
24.507 Reactor Engineering and Safety Analysis
24.509 Dynamic Systems Analysis

Plastics:
26.503 Mechanical Behavior of Polymers
26.506 Polymer Structure, Properties

and Applications
26.518 Plastic Products Design
26.552 Design of Polymer Processing Machinery
26.523 Plastics Process Analysis
Advanced Mold Design

Certificate Programs

Non-degree candidates who have a B.S. in engineering or a physical science are encouraged to take a 12 credit-hour concentration. A certificate will be awarded upon successful completion. Eligibility for this certificate program is a B.S. in an engineering discipline or physical science at an acceptable grade point average. Certificate programs available include:

Manufacturing
Finite Element Analysis
Modal Analysis and Vibrations
Mechanics of Materials
Thermal Fluids
Structural Modeling

Interdisciplinary Program with the College of Management

The three graduate courses, 22.571 (Concurrent Engineering and Quality), 22.573 (Manufacturing Systems Engineering), and 22.579 (Robotics) are part of the Master of Management Science in Manufacturing offered by the College of Management. This degree is intended to enhance state and regional economic development by improving manufacturing competitiveness. The curriculum dually focuses on state-of-the-art management and engineering skills that are integrated to foster more effective leadership in manufacturing settings. Application is made through the College of Management.

B.S./M.S. PROGRAM

For its undergraduate students, the department offers a combined B.S./M.S. program. This program is an option available to undergraduates with a minimum 3.0 grade point average at the end of their junior year. Application for the B.S./M.S. program should be made to the graduate coordinator by the eighth week of the second semester of the junior year. These applications will be held by the graduate coordinator until the grades for complete junior year are obtained. The University requirement that all graduate school applicants take the Graduate Record Examination (GRE) is waived. Two graduate courses are taken in the senior year and the six credits obtained are applied to the B.S. degree requirements; in addition, if a grade of B or better is obtained in these courses they can be applied to the M.S. degree requirements. Students may take more graduate credits as a BSME student. However, only 6 credits (typically two courses) may be counted toward both degrees.

DOCTOR OF ENGINEERING DEGREE

The intent of the Doctor of Engineering program is to prepare engineers for leadership positions in industry and government, and educators in the areas of design and manufacturing as well as in general areas of mechanical engineering science. It thus consists of a rigorous theoretical and technical thrust and includes an emphasis on management skill development. It also offers doctoral candidates an opportunity to develop teaching experience in all areas of concentration.

Admission Requirements

The admission requirements as set forth by the University are to be followed. The applicant is required to have an M.S. degree, or have completed fifteen credit hours of graduate study in engineering or its equivalent with a minimum grade point average of 3.25. Students may apply and transfer up to 24 credit hours of graduate course work toward the doctoral degree. In cases where a student has an M.B.A., in addition to a B.S. in engineering or its equivalent, the management portion of the Doctor of Engineering program may be waived.

Degree Requirements

A total of 63 credit hours of graduate level courses are required for the Doctor of Engineering degree. The general degree requirements are as follows:

1. 33 approved credit hours of graduate level engineering courses, including the core requirements of the M.S. program and seminar.
2. A two course sequence in advanced mathematics (with approval of the graduate coordinator).
3. 9 credit hours of management/non-technical courses.
4. 21 credit hours for the dissertation.
5. The student is required to be in full-time residency at the University for at least one year.
6. The student must have a minimum grade point average of 3.25 in order to graduate.

Students are required to take the qualifying examination at the beginning of their second semester in the program. Exceptions may be made for students whose Master Degree is in a discipline other than engineering. Students may register for no more than six credit hours of research in preparing a formal dissertation proposal. This proposal and the student's ability to perform the research must be orally defended before the student's doctoral committee and other interested parties. This constitutes the candidacy examination. Upon passing this examination and completing all course requirements, the student becomes a candidate for the D.Eng. degree and may register for additional research credit with the advisor's approval.

Qualifying Examination

1. The student is permitted two attempts at passing the qualifying examination which is administered on a declared schedule. Students who fail the qualifying examination the first time must retake the exam at its next scheduled offering. Students failing the doctoral exam twice will automatically be dismissed from the doctoral program. Those who do not take the examination at the prescribed time may lose all their financial support, if any, and may be dismissed from the doctoral program.
2. The written part of the examination is closed book and composed of two sections, each of three hours duration. The examination is evaluated by the Graduate Examination Committee which determines whether or not a student shall be eligible to take the oral part.
3. Students who pass the written part of the qualifying examination must take the oral part of the examination within 6 weeks of notification of results of the written exam.
4. The Graduate Examination Committee will report its assessment of the student's performance to the Graduate Faculty of the Mechanical Engineering Department for the final decision as to whether or not the student passed the qualifying examination in its entirety.

Dissertation

The research work for the dissertation shall be conducted under the supervision

of a departmental faculty advisor and a committee of two others, at least one of whom must be a faculty member in the Mechanical Engineering Department.

PH.D. DEGREE IN APPLIED PHYSICS

A program offering a Ph.D. in Applied Physics with a concentration in Applied Mechanics is offered jointly by the Departments of Physics and Mechanical Engineering. This program is delineated below:

1. General Required Courses
   (a) Basic courses include two semesters of Electromagnetism, two semesters of Introduction to Quantum Mechanics and one semester of Introduction to Classical Mechanics.
   (b) Advanced courses include two semesters of Mathematical Physics, one semester of Thermodynamics & Statistical Mechanics, one semester of Electromagnetic Theory and one semester of Classical Mechanics.
   (c) In addition, appropriate courses in applied mechanics offered by the Mechanical Engineering Department will be taken as required by the student's advisor.
2. Qualifying Examination

The qualifying examination is administered in accordance with the requirements by the Department of Physics.

3. Language Requirement

There is a requirement for proficiency in two languages from among French, German, Spanish, or Russian. However, a computer language may be substituted for one of the languages.

4. Dissertation Requirements

A thesis based on original research performed under the supervision of a faculty member is required.

Enrollment in Courses

Only matriculated students can take advantage of early enrollments in courses. All other students must wait until late registration just before the start of each semester. Students must obtain the approval of their advisor before meeting with the graduate coordinator for registration.

COURSE DESCRIPTIONS

22.510 Introduction to Modal Analysis (3-0)3 Introduction to experimental modal analysis. Development of system and transfer matrices; development of the frequency response matrix; relationship between system matrices, frequency response matrix and system mode shapes. Basic digital signal processing for experimental modal analysis; development of FRF from measured data; test data collected using FFT analyzers. Basic modal parameter estimation techniques. Models developed using MATLAB and commercially available software.

22.512 Applied Finite Element Methods (3-0)3 An introduction into finite element methods using popular commercial packages. The features common to different programs as well as special features of particular programs are presented. Primary focus is on hands-on familiarity of the software with a limited discussion of the underlying finite element theory. ALGOR, ADINA, ABAQUS, LS-DYNA, NASTRAN, PATRAN, DYTRAN, ANSYS, HyperMesh, and FEMAP are among the pre/postprocessing and analysis packages used in the class. This is a self-paced World Wide Web based course and access to a PC, the internet, and a frames capable browser is required.

22.513 Finite Element Methods (3-0)3 Matrix algebra and the Rayleigh-Ritz technique are applied to the development of the finite element method. The minimum potential energy theorem, calculus of variations, Galerkin's and the direct-stiffness method are used. Restraint and constraint conditions are covered. C0 and C1 continuous shape functions are developed for bar, beam, and two- and three-dimensional solid elements. Recovery methods, convergence and modeling techniques are studied. Applications to problems in static stress analysis and heat conduction.

22.515 Modal Analysis - Theoretical Methods (2-0)2 Review of single and multiple degree of freedom system using classical and Laplace formulations. Finite element methods for dynamic systems. Model reduction/expansion formulations. Modal participation and mode activation concepts. Linear algebra review, matrix formulations, matrix eigenanalysis, generalized inverses, spectral and singular valued decomposition techniques. Models developed using MATLAB.

22.516 Experimental Modal Analysis (2-0)2 Prerequisite: 22.510 (or permission of instructor) Review of system transfer and FRF matrices for development of a modal model. Review of DSP techniques for experimental modal analysis. Excitation techniques for the development of the system FRF matrix; SISO and MIMO techniques. Modal parameter estimation using time and frequency domain techniques. Advanced data manipulation for dynamic analysis. Models developed using MATLAB and commercially available software.

22.517 Structural Dynamics (2-0)2 Prerequiste: 22.515 Development of system equations of motion for multi-DOF systems. Proportional and non-proportional damping. Dynamic response using mode superposition, maximum response, frequency domain techniques and direct integration using central difference, Runge-Kutta, Wilson theta, and other techniques. Models developed using MATLAB.

22.518 Dynamic System Modeling (2-0)2 Prerequiste: 22.515 Development of the structural dynamic modification procedure; eigenvalue modification techniques. Review of system modeling techniques using physical models, reduced models, modal models and hybrid models. Integration of analytical and experimental data for the development of system models. Force extraction techniques using operating data and system transfer relations. Models developed using MATLAB.

22.519 Dynamic Model Correlation (2-0)2 Prerequiste: 22.515 Development of modal model correlation techniques. Vector correlation, DOF correlation and FRF correlation. Models developed using MATLAB as well as commercially available software.

22.521 Solar Fundamentals (3-0) 3 Terrestrial irradiation on tilted surfaces; radiation, conduction, convection in collectors; absorptance, emittance, reflection, transmittance of solar irradiation; energy flow in flat plate and concentrator collectors; storage; design tools; small project.

22.527 Solar Systems Engineering (3-0)3 Passive solar heating and cooling, photovoltaic, and daylighting systems design and analysis with steady-state, dynamic, and stochastic models as well as life-cycle cost/benefit analysis. Small design project.

22.534 Applied Numerical Methods (3-0)3 Number systems and error. Gaussian methods of linear algebra. Matrix eigenvalues. Difference and summation calculus. Interpolation. Definite integrals. Differential equation modeling and stability. Orthogonal polynomials. Roots of polynomials. Zeroes of single variable functions. Optimization.

22.540 Conduction Heat Transfer (2-0)2 Analytical solution of problems in one-dimensional transient heat conduction, and two-dimensional steady state heat conduction. A finite element computer package is used to compare the analytic solutions to numerical predictions and to extend the solutions to more complex problems for which there are no analytic solutions. No formal training in the finite element technique is required for this course.

22. 541 Radiation Heat Transfer (2-0)2 Radiative heat transfer between surfaces and participating media.

22.542 Convective Heat and Mass Transfer

(2-0)2 Conservation equations. Heat transfer in laminar and turbulent boundary layer and duct flow. Free convection. Convective mass transfer.

22.543 Analytical and Numerical Methods in Heat Conduction (3-0)3

22.546 Numerical Methods in Thermo-Fluid Systems I (Fundamental): (2-0)2 Fundamentals of finite difference schemes: stability, consistency and accuracy of different numerical techniques.

22.548 Numerical Methods in Thermo-Fluid Systems II (Application): (2-0)2 Application of state-of-the-art numerical methods to the solution of problems involving fluid flow, heat transfer, chemical reactions and turbulence.

22.550 Vibrations (3-0)3 Modeling and solution of multi-degree of freedom problems. Matrix methods are used along with an applications program. Shock spectrum methods and non-linear effects are considered.

22.551 Advanced Dynamics (3-0)3 Formulation of advanced representations of kinematics and dynamics. Development of Lagrangian and Hamiltonian dynamic equations. Dynamics of systems with constrained motion. Principal of virtual work. Gyroscopic effects. Introduction to nonholonomic systems.

22.554 Dynamic Systems and Control (3-0)3 Matrix-based classical and modern techniques are applied to the dynamics of control systems. Design of controllers, and full and reduced-order observers. Introduction to optimal control and Kalman filters.

22.556 Stochastic Processes (3-0)3 Introduction to stochastic processes with emphasis on time domain analysis. Probability theory review, continuous and discrete joint distributions, moments. Gaussian, Markov, stationary, and Poisson processes. Noisy dynamic systems, time series analysis, Kalman filtering, geometric foundations.

22.562 Solid Mechanics I (2-0)2 Prerequisite: 22.531. Topics covered include the theory of stress, kinematics of strain, Hooke's Law, work and energy, equations of stress equilibrium, Navier's equations, strain compatibility, and the Beltrami-Michell equations. Problems for uniformly varying 3-D states of stress, torsion, and plane deformation are studied.

22.563 Solid Mechanics II (2-0)2 A continuation of Solid Mechanics I. Axisymmetric deformation is considered. Green's function solutions and Hertz contact problems are covered. The propagation of compressive, shear, surface and interface waves are studied.

22.569 Finite Element Methods in Thermofluids The transport equations of thermofluids are reviewed. The Galerkin technique is applied to develop a finite element representation of simple one-dimensional problems involving convection and diffusion. The technique is extended to multiple-dimension and transient problems. Computer based applications and examples are introduced. This is a World Wide Web based course and access to a PC, the internet, and a frames capable browser is required. An undergraduate exposure to the following topics is required: Matrix Algebra, Integral and Differential Calculus, Vector Calculus, Heat Transfer, Fluid Flow.

22.571 Concurrent Engineering and Quality (3-0)3 This course focuses on the methodologies used by world class companies to guide the development and design of high quality, low cost products in the most timely fashion, through the use of analytical tools an case studies. Topics include the new product creation strategy and process, and structural methodologies for identifying customer requirements and manufacturing process design, control and selection. Tools discussed include Cp, Cpk, Six Sigma, Control Charts, DFM, Design for Quality and the Environment, QFD and Design theories. In particular, the course will focus on the interrelationship of CE and Quality tools and methodologies and how they contribute in determining the appropriate level of product/process quality and design efficiency

22.572 Manufacturing Processes (3-0)3 Ferrous and non-ferrous, plastic and ceramic material behavior and properties. Electronic manufacturing processes, including printed circuit board fabrication, population and soldering. Castings, materials forming and shaping. Surface preparations and heat treatment. Joining processes, welding design and selection.

22.573 Manufacturing Systems Engineering (3-0)3 Performance measures and automated manufacturing processes overview; stochastic processes; Markov chain models; queueing theory and applications; reliability, life testing; optimization overview; linear programming; Simplex Method; integer programming.

22.575 Industrial Design of Experiments (3-0)3 Concepts of Robust Design and statistical Design Of Experiments (DOE) as applied to the design and manufacturing of new high technology products. Classical and current methodologies of DOE including Full Factorial, Fractional Factorial, Taguchi, Central Composite and Yates Algorithms. The course will also provide for different methods for experimental design and analysis, including average and variability analysis. Commercial software packages and case studies using industrial experiments will be used to illustrate the material.

22.577 Event Driven Manufacturing (3-0)3 This course develops and applies the tools to analyze, predict and control production flow under diverse product manufacturing conditions. Topics covered include, group technology, the Li/Parkin sorting algorithm, multi-dimensional category sorting, time-driven simulation systems, event-driven simulation, product assembly templates, production simulation and scheduling, bottleneck identification, and hierarchical system interrogation.

22.579 Robotics (3-0)3 Common robotic joints and robotic classification. Planes of motion and fold lines. Robotic capability. Forward and inverse kinematics and the RobSim software package. Trajectory planning and elementary obstacle avoidance. Robotic dynamics and feasible trajectory evaluation. Design of the control system for the nonlinear robotic problem. Classroom studies are followed by hands-on applications in the Automated Manufacturing Assembly and Robotics Laboratory.

22.581 Advanced Fluid Mechanics (3-0)3 Corequisite: 92.545 or equivalent. Fundamental equations of fluid motion, kinematics, vorticity, circulation, Crocco's theorem, Kelvin's theorem, Helmholtz's vorticity laws, secondary flows. Stream function, velocity potential, potential flows. Unsteady Bernoulli equation, gravity water waves.

22.582 Viscous Flow (2-0)2 Derivation of Navier-Stokes equations. Examples of exact solutions. Laminar and turbulent boundary layer. Low Reynolds number flow.

22.583 Advanced Aerodynamics (3-0)3 Fundamentals of subsonic and supersonic aerodynamics. Atmosphere models, air-speed measurement, and aerodynamic heating. Circulation, downwash, and three-dimensional wing theory. Airfoil data, and lift and drag of aircraft components. Compressibility effects on drag, and airfoils and wings in supersonic and hypersonic flow. Aircraft performance calculations. Fundamentals of orbital mechanics. Special project required in supersonic wind tunnel testing or orbital mechanics.

22.587 Applied Numerical Methods (3-0)3 Number systems and error. Gaussian methods of linear algebra. Matrix eigenvalues. Difference and summation calculus. Interpolation. Definite integrals. Differential equation modeling and stability. Orthogonal polynomials. Roots of polynomials. Zeros of single variable functions. Optimization.

22.589 Finite Element Method in Thermofluids (2-0)2 The Galerkin finite element technique is first applied to a simple one-dimensional steady state convection/conduction equation. The element equations are derived and the assembly process is described. These concepts are then extended to two-dimensional transient problems. A finite element package is used to solve a variety of fluid flow problems. All course materials are available on the WWW.

22.590 Control Volume Finite Element Methods in Thermofluids (3-0)3 Pre-requisites 22.546. This advanced course extends the concepts learned in (22.546) to general unstructured meshes. The theory of control volume finite elements is developed for a two-dimensional steady state convection/diffusion equation. The general transport

equations are then developed using vector calculus techniques. A computer package is used to solve advanced problems in laminar and turbulent heat, mass, and momentum transfer. All course materials are available on the WWW although potential remote learners will have to have access to an appropriate computer package.

22.591 Mechanical Behavior of Materials (3-0)3 Quantification of structure-property relationships requires application of solid mechanics concepts to materials microstructure. Using micromechanics approach, the course focuses on the deformation and fracture behavior of metals, ceramics, composites and polymerics. Topics include: elastic behavior, dislocations, crystal plasticity, strengthening mechanisms, composite materials, glassy materials, creep and creep fracture, tensile fracture, and fatigue.

22.593 Failure Analysis (2-0)2 The prediction, analysis, and prevention of failure in mechanical design is covered. Failure mechanisms such as creep, plastic deformation, crack propagation, cyclic fatigue, thermal fatigue, fretting and galling are considered. Theories of failure such as Coulomb-Mohr, Beltrami, and Huber-Von Mises are used to predict failure. Cumulative damage theories such as those of Gatts, Corten and Dolan, Marin, and Manson will be studied. Statistical methods of analysis and test data interpretation are studied. Materials such as steels, aluminum alloys, solders, plastics, and composites will be considered.

22.596 Composite Materials (2-0)2 Analysis of anisotropic lamina and laminated composites. Methods of fabrication and testing of composites. Other topics include environmental effects, joining and machining.

22.597 Composites Processing (2-0)2 Methods of fabrication. Analysis of forming, fiber orientation, permeability, polymer rheology, flow through porous media, consolidation, cure kinetics, combined flow and cure models. Effect of manufacturing defects.

22.601 Selected Topics in Mechanics and Machine Design (3-0)3 Study of advanced topics in mechanics and machine design not covered in the regular curriculum. Contents may vary from year to year.

22.602 Selected Topics in Thermo-Fluid/Energy Systems (3-0)3 Study of advanced topics in thermo fluid/energy systems and processes not covered in the regular curriculum. Contents may vary from year to year.

22.603 Selected Topics in Vibrations/ Dynamics (3-0)3 Study of advanced topics in vibrations/dynamics not covered in the regular curriculum. Contents may vary from year to year.

22.604 Selected Topics in Design and Manufacturing (3-0)3 Study of advanced topics in design and manufacturing not covered in the regular curriculum. Contents may vary from year to year.

22.606 Advanced Directed Studies in Mechanical Engineering (3-0)3 The course gives an opportunity for an in depth study of some aspect of mechanical engineering under the close supervision of a faculty member.

22.611 Matrix Methods (2-0)2 Prerequiste: 22.515. Matrix linear algebra. Solution of algebraic equations using Gaussian elimination and decomposition variants. Eigenanalysis using various direct similarity techniques and simultaneous vector iteration methods. Algorithm development of solution techniques. Solution techniques for structural mechanics, dynamic systems and stability. Models developed using MATLAB.

22.612 Model Updating (2-0)2 Prerequiste: 22.515. Review of model updating procedures. Optimization and localization of model errors. Models developed using MATLAB as well as commercially available software.

22.614 Nonlinear Finite Element Methods (3-0)3 Nonlinear finite element methods as applied to large deformation and nonlinear material behavior and contact problems are the focus of this course. Various classical and contemporary constitutive models and their implementation in the finite element method are considered. Procedures for determining material parameters from a matrix of material test results are investigated. Commercial and student-written software is used.

22.615 FEA of Composites (2-0)2 Material models for FEA of composite structures. Critical comparison of FEA and experimental results.

22.644 Plate Theory (2-0)2 The theory of plates is developed from first principles from the equations of elasticity using integral averaging. Solutions to bending, buckling, vibration and forced motion problems are obtained for rectangular and circular plates.

22.645 Shell Theory (2-0)2 The membrane theory of shells and the general bending theory of shells are developed from first principles from the equations of elasticity using integral averaging. Solutions to bending, buckling, vibration and forced motion problems are obtained for a variety of practical shell problems.

22.678 Workcell Design and Control (3-0)3 Prerequisite: 22.579. Imaging of objects, hidden line removal and the PolyCAD mask decomposition system. Object generation - extruding, turning, drilling and cutting. Geometry of the work place and collision detection. Automatic obstacle avoidance. Multiple manipulation kinematics. High level trajectory planning and coordinated control. Sensory feedback systems and robotics autonomy. Applications of the RobSim software package. Classroom studies are followed by hands-on applications in the Automated Manufacturing Assembly and Robotics Laboratory.

22.697 Structural Application of Composite Materials (2-0)2 Prerequisite: 22.596. Study of constitutive relationships for anisotropic materials and application of these materials to structural elements such as beams, plates and shells. Problem areas considered include bending, buckling, fracture and vibrations.

22.743 MS Thesis Research (0-6)3
22.746 MS Thesis Research (0-12)6
22.749 MS Thesis Research (0-18)9
Prerequisite: a minimum of 9 credit hours of graduate courses at an acceptable level.

22.753 Doctoral Dissertation Research (0-6)3
22.756 Doctoral Dissertation Research (0-12)6
22.759 Doctoral Dissertation Research (0-18)9 Masters and doctoral students who have attained the required number of thesis credits may enroll in:

22.763 Continuing Graduate Research (0-6)3
22.766 Continuing Graduate Research (0-12)6
22.769 Continuing Graduate Research (0-18)9

DEPARTMENT OF PLASTICS ENGINEERING

Department Head
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Professor; B.S., Alexandria University; S.M., M.E., Sc.D., Massachusetts Institute of Technology.

MASTER OF SCIENCE IN ENGINEERING DEGREE PROGRAM

The graduate program offers professional training at the master's level designed to provide the opportunity for the study of more advanced theory and practice in plastics, man-made fibers, rubber, coatings, and adhesives, and to broaden the background of experienced members of the profession to help them keep up with the latest fundamental developments in the field.

The Department of Plastics Engineering offers a Master of Science in Engineering (M.S.E.) in Plastics Engineering. In addition, the M.S.E. degree offerings are divided into three concentrations and two options. The concentrations are plastics materials, design, and processing; while the options are fibers/composites, and coatings and adhesives. Additionally, students whose interests are not specialized within one of the specific concentrations or options may follow the course of study listed under the heading of General Curriculum. The M.S.E. degree will be awarded upon satisfactory completion of 30 credit hours of study, of which the mandatory thesis provides six credits.

Admission Requirements

In addition to the requirements listed earlier in this catalog, admission to the program is open to candidates with a B.S. in Plastics Engineering or a related field. Candidates with degrees in other fields of science or engineering, from other schools, or industrial experience in place of University of Massachusetts Lowell B.S. courses in plastics, shall take the foundation courses they lack as prerequisites before undertaking the graduate courses in plastics. These foundation courses comprise a sequence of 16 credits as listed below:

26.543	Survey of Plastics Materials I	3
26.544	Survey of Plastics Materials II	3
26.577	Plastics Processing Engineering I	3
26.578	Plastics Processing Engineering II	3
26.571/2	Plastics Processing Eng. Lab. I/II	2
26.573/4	Plastics Physical Prop. Lab. I/II	2
	TOTAL:	16

None of these 16 credit hours may be used to satisfy the 30 credit hours required for the completion of the M.S.E.

degree. The Graduate Record Examination Aptitude test is required for this program.

Advisors and Advisory Committee

The graduate coordinator will be the academic advisor for each student, to help him or her remedy deficiencies in prerequisites, select electives of most value, and plan the overall study program efficiently. The thesis advisor will be chairperson of the thesis advisory committee which will guide the student in the thesis research and supervise the completion of the thesis requirement.

Plastics Engineering

Students with a B.S. in Plastics Engineering at UMass Lowell may earn an M.S.E. in Plastics Engineering by completing one of the courses of study listed later.

Students with a B.S. in another field of engineering may earn an M.S.E. in Plastics Engineering by following one of the listed curricula, in addition to completing the 16-credits of foundation courses listed above.

Students with a non-engineering B.S. may earn an M.S.E. in Plastics Engineering after completion of the 16-credits of foundation courses and any one of the listed curricula, and by making up any necessary prerequisites in mathematics and general engineering that may be assigned by the graduate coordinator at the time of admission.

B.S./M.S. ENGINEERING DEGREE PROGRAM

A five-year B.S./M.S. Eng. program is available to undergraduates with a cumulative grade point average of at least 3.00 at the end of their junior year. The department allows the transfer of up to eight credits used towards the B.S. degree in Plastics Engineering to be used to fulfill the requirements of the M.S.E. degree. See the front of the catalog for the general university requirements.

Plastics Materials Concentration

Required Courses

26.503	Mechanical Behavior of Polymers	3
26.506	Polymer Structure, Properties, and Applications	3
26.580/1	Polymer Science I/II	6
26.5XX	Materials/Design/Processing Seminars	3
	TOTAL:	15

Choose two of the following:

26.505	Polymers Structure II	3
26.511	Polymer Blends	3
26.512	Foams	3
26.513	New Plastic Materials	3
26.516	Composite Materials	3
26.532	Adhesives	3
26.533/4	Coating Science and Technology I/II	6
26.535	Rubber	3
26.536	Rheology of Coatings	3
26.540	Commercial Development of Polymers	3
26.553/4	Polymers in Medicine I/II	6
26.555/6	Rheology I & II	6
26.559	Elements of Packaging	3
26.565	Engineering Polymers	3
26.566	Polymeric Materials Systems Selection	3
26.583	Advanced Research Methodology	3
26.595	Thermoplastic Elastomers	3
26.598	Smart Polymers	3
Plus one elective 26.5XX		3
Plus Thesis Research in Plastics Materials		6
	TOTAL:	30

Design Concentration

Required Courses

26.503	Mechanical Behavior of Polymers	3
26.506	Polymer Structure, Properties, and Applications	3
26.518	Plastics Product Design	3
26.585	Computer Aided Engineering and Design I	3
26.5XX	Materials/Design/ Processing Seminars	3
		15

Choose three of the following:

26.509	Plastics Processing Theory	3
26.523	Plastics Process Design	3
26.541	Computer Applications	3
26.552	Design of Polymer Processing Machinery	3
26.576	Advanced Mold Design	3
26.586	Computer Aided Engineering and Design II	3
26.599	Rapid Prototyping	3
97.503	Polymer Science (or 26-580)	3
26.5XX	Elective	3
Plus Thesis Research in Plastics Design 26.743/6		
	TOTAL:	30

Processing Concentration

Required Courses

26.506	Polymer Structure, Properties & Applications	3
26.509	Polymer Processing Theory I	3
26.510	Polymer Processing Theory II	3
26.552	Design of Polymer Processing Machinery	3
26.5XX	Materials/Design/ Processing Seminars	3
		15

Choose three of the following:

26.518	Plastics Product Design	3
26.523	Plastics Process Design Analysis	3
26.524	Process Control	3
26.557	Composites Fabrication	3
26.583	Research Methodology (Design of Exp.)	3
26.585	Computer Aided Engineering and Design I	3
26.5XX	Elective	3
Plus Thesis Research in Plastics Processing 26.743/6		6
	TOTAL:	30

Fiber/Composites Option

Required Courses

26.503	Mechanical Behavior of Polymers	3
26.509	Plastics Processing Theory I	3
26.516	Composite Materials	3
26.525	Proc. of Syn. Fibers & Fibrous Struct.	3
26.527	Mechanics of Fibrous Structures	3
26.557	Composites Fabrication	3
26.5XX	Materials/Design/ Processing Seminars	3
		21

Choose one of the following:

26.504	Physical Properties of Polymers	3
26.506	Polymer Structure, Properties, and Applications	3
26.526	Adv. Processing of Fibers and Fibrous Structures	3
26.529	Fiber Evaluation	3
26.552	Design of Polymer Processing Machinery	3
22.597	Structural Applications of Composites	3
22.598	Case Studies in Composites	3
97.503	Polymer Science I (or 26.580)	3
		24

Plus Thesis Research in Fiber/Composites 26.743/6 6

TOTAL: 30

Coatings and Adhesives Option

Required Courses

26.533/4	Coatings Science and Technology I & II	6
26.580/581	Polymer Science I & II	6

26.503	Mechanical Behavior of Polymers	3
26.536	Rheology of Coatings	3
26.532	Adhesives and Adhesion	3
26.5XX	Materials/Design/ Processing Seminars	3
		24
Plus Thesis Research in Coatings and Adhesives 26.743/6		6
	TOTAL:	30

General Curriculum

Required Courses

26.503	Mechanical Behavior of Polymers	3
26.506	Polymer Structure, Properties, and Applications	3
Or		
26.518	Plastics Product Design	
26.5XX	Graduate Electives	15
26.5XX	Materials/Design/Processing Seminars	3
Plus Thesis Research in Plastics Engineering 26.743/6		6
	TOTAL:	30

DOCTOR OF ENGINEERING DEGREE PROGRAM

The Doctor of Engineering in Plastics Engineering is designed to produce qualified professionals for technical management positions in the plastics industry, as well as for administrative positions in government and for teaching careers in colleges and universities.

Objective

The goal of the Doctor of Engineering program is to develop decision-making engineers with sound theoretical and technical research knowledge who are design and development oriented and who also have a firm background in engineering management. This interdisciplinary program encompasses study in materials, design, processing, mathematics, computer science, and management.

Admission Requirements

Graduates with a B.S. in Plastics Engineering and high academic standing may apply to the Graduate School for admission to the program. Graduates from other schools or in other fields of engineering will be required to make up any prerequisites which they lack in comparison to the B.S. Plastics Engineering curriculum at the University of Massachusetts Lowell. Technical graduates who do not have a B.S. in engineering may request admission to the program with the understandng that they will also be required to make up the general mathematics, science and engineering courses which they lack. Admission to the program will be based on review by the graduate School and by the Admissions Committee of the Plastics Engineering Department.

Plan of the Program

Each student entering the program must develop a plan of study in consultation with his or her advisory committee. After satisfying the prerequisites and taking one year of graduate courses, the student will take a qualifying examination covering all the basic elements of plastics engineering. A student who performs well on this examination will be reviewed by the Admissions Committee of the Plastics Engineering Department and admitted to degree candidacy. He or she will then complete the remaining course work, seminars, internship, dissertation, and oral defense of the research.

Qualifying Examination

The qualifying examination will be administered twice a year in January and May. It will be a day-long examination, covering the following topics: engineering fundamentals, processing, design, properties, and materials. Any changes to the format will be indicated by the doctoral coordinator when the specific examination date is announced. The student will receive a grade of pass or fail. A student who fails the exam on a marginal basis may make a second attempt with permission of the Graduate Study Committee. All decisions of the Plastics Engineering Department regarding passing of the qualifying exam are final.

Dissertation Proposal

Once the student has passed the qualifying exam, he or she may submit a dissertation proposal and defend the proposal before the Doctoral Committee. Upon approval, the student's name will be submitted to the College Doctoral Committee and the Dean of the Graduate School as a candidate for the Doctor of Engineering degree. Admission to candidacy status does not guarantee awarding of the degree.

Transfer Credit

Up to 24 credits in graduate engineering courses are transferable to the Doctor of Engineering program upon approval by the department's Doctor of Engineering Committee.

Other Requirements

A student must maintain high academic standing throughout the pursuit of the degree. He or she must spend at least one year at the University with full-time graduate student status to fulfill the university residence requirement.

Course Requirements

The following courses are required for the degree:

26.503	Mechanical Behavior of Polymers	3
26.506	Polymer Structure, Properties and Applications	3
26.509/10	Plastics Processing Theory I/II	6
26.518	Plastics Product Design	3
26.547	Analytical Methods	3
26.548	Numerical Methods in Plastics Processing	3
26.585/86	Computer Aided Engineering and Design	6
26.XXX	Plastics Seminars	3
	Engineering Elective	3
	Engineering Management Courses	9
	Doctoral Research Dissertation	21
	TOTAL:	63

DOCTOR OF PHILOSOPHY DEGREE PROGRAM

A doctoral program in Chemistry with an option in Polymer Science/Plastics Engineering is offered jointly with the Polymer Science group in the Department of Chemistry. This program is designed to provide the student with a background in advanced course work and laboratory techniques which will prepare him or her to carry out, under the guidance of experienced scientists, an original, independent investigation leading to an acceptable contribution to the body of contemporary knowledge. Further details of the program are described in the Chemistry section of this catalog.

COURSE DESCRIPTIONS

26.502 New Plastics Processing Techniques* (3-0)3 Critical examination of new plastics processing techniques appearing in the research literature and being commercialized in the plastics industry.

26.503 Mechanical Behavior of Polymers (3-0)3 Mechanical properties of bulk polymers. Linear viscoelasticity, creep, relaxation, dynamic and stress/strain response phenome-

na. Principles of time/temperature superposition. Rubber elasticity. Failure behavior of polymeric materials.

26.504 Physical Properties of Polymers* (3-0)3 Polymers as linear viscoelastic materials. Creep, stress relaxation, superposition, dynamic mechanical behavior, electrical behavior, miscellaneous mechanical properties, optical properties, transport properties.

26.505 Polymer Structure II (3-0)3 Continuation of 26.506.

26.506 Polymer Structure, Properties, and Applications (3-0)3 Relationships between polymer structure (chemical composition, molecular weight and flexibility, intermolecular order and bonding, supermolecular structure) and practical properties (mechanical, acoustic, thermal, electrical, optical and chemical) and applications.

26.507 Plastics Industry Organization (3-0)3 Economics of producing plastic raw materials and converting them into end products, from research and development to plant construction, manufacturing and marketing. Market analysis of plastics production, processing, and consumer patterns; commercial development, sales, and technical service.

26.509 Plastics Processing Theory I (3-0)3 Principles of rheology and continuum mechanics involved in the processing of plastics, and their applications in plastics process engineering including flows in standard geometrical and extrusion applications.

25.510 Plastics Processing Theory II (3-0)3 A continuation of Theory I using the transport phenomena approach to analyze and describe plastics conversion processes, including roll processing blown film extrusion, injection molding, and mixing.

26.511 Polymer Blends and Multiphase Systems* (3-0)3 Physical, mechanical and thermal properties, preparation, and testing of polymer blends, alloys, and multiphase systems. Thermodynamic theories and experimental determination of miscibility of polymer blends. Structure-property relationships for multiphase systems and interpenetrating networks.

26.512 Plastics Foams* (3-0)3 Preparation, structure, and properties of plastics foams. Practical systems in development and production. Properties, applications, and markets for plastics foams and products made from them.

26.513 New Plastics Materials* (3-0)3 Critical examination of the new plastics appearing in the research literature and being field-tested for commercialization in the plastics industry.

26.516 Composite Materials (3-0)3 Composite materials for structural applications. The behavior of constituent materials, i.e. metals, polymers and ceramics. The nature of short fiber composites is briefly examined. Methods of analyzing orthotropic lamina and laminated composites are studied. Three dimensionally reinforced composites are introducted and analyzed. Other topics include methods of fabrication, testing, joining, environmental effects and the effects of defects on the performance of composites.

26.518 Product Design (3-0)3 Theoretical principles and sound engineering practice involved in the design of new end products made from polymers, applying the total systems approach to the balance between product design, choice of materials, and process technique, as they affect competitive choice for commercial success.

26.519 Plastics Coatings in Electronics* (3-0)3 The role of plastics coatings in electronics. Chemical, electrical, thermal, and mechanical characteristics of each major plastic family. Manufacturing technology for applying them.

26.523 Plastics Process Analysis (3-0)3 Analysis of batch and continuous processes. Dimensional analysis. Thermodynamic properties of thermoplastics, enthalpy, heat capacity, sensible heat, heat of fusion, and heat of reaction. Scale-up and modeling of processes. PVT analysis of injection molding. Heat transfer with phase change. Applications in plasticating screw design for extrusion and injection molding.

26.524 Process Analysis, Instrumentation, and Control* (3-0)3 Industrial instruments for measurement and control of plastics processes. Design of experiments. Analysis of plastics forming operations. Dynamic testing techniques. Automatic plastics process control. Modeling and process simulation in extrusion and injection molding. Data acquisition systems.

26.525 Processing of Fibers and Fibrous Structures* (3-0)3 An introduction to systems utilized in the processing of fiber structures. These include drawing, winding, texturing, staple fiber production, blending, static control, dyeing and finishing. The effect of these mechanical, physical, and chemical processes on the resultant fiber and fibrous structure behavior. Fibrous structures considered as reinforcements for composite materials.

26.526 Advanced Processing of Fibers and Fibrous Structures* (3-0)3 A continuation of 26-525 to include woven, knitted, nonwoven and non-conventional fibrous structures.

26.527 Mechanics of Fibrous Structures* (3-0)3 Characteristics of fibers as affecting performance of conventional and non-conventional fibrous structures. Design considerations and mechanical behavior of twisted, knitted, woven, braided, and nonwoven fibrous materials.

26.528 Plastics Information Seminar (1-0)1 Review of procedures for literature searching, data bases, etc.

26.529 Fiber Evaluation* (3-0)3 An introduction to the evaluation of textile structures as reinforcements for composite materials. Fibers, yarns and fabrics of carbon, boron, silicon carbide and Kevlar are considered in terms of the effects of their properties on the processing and structural behavior of composite materials.

26.530 Selected Topics: Plastics I (3-0)3 Topics in various fields of Plastics Engineering. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary Plastics Engineering.

26.532 Adhesives and Adhesion* (3-0)3 Adhesive joining of engineering materials. Surface chemistry, theories of adhesion and cohesion, joint design, surface preparation, commercial adhesives, rheology, equipment, testing, service life, and reliability.

26.533/4 Coatings Science and Technology I & II* (3-0)(3-0)6 Polymers, pigments, solvents, and additives used in coatings. Methods of polymerization, formulation, application, and testing. Substrates and applications.

26.535 Rubber* (3-0)3 Polymerization and compounding of the commercial elastomers. Properties and test methods. Leading applications and methods of processing.

26.536 Rheology of Coatings* (3-0)3 Rheology of polymer melts, solutions, latexes and pigment dispersions, and their application to coatings and adhesives.

26.537 Engineering Properties of Plastics* (3-0)3 Theoretical basis and practical significance of the mechanical, thermal, electrical, optical, and chemical properties of plastic materials. Importance of engineering properties in material development and selection and in product design.

26.538 Selected Topics : Plastics II (3-0)3 Continuation of 26.530.

26.539 Selected Topics: Plastics III (3-0)3 Continuation of 26.530.

26.540 Commercial Development of Polymeric Systems* (3-0)3 The concepts of industrial marketing will be reviewed for research, pricing strategies, and product planning for market segmentation, place (distribution)-promotional activities. Topics will include creating a demand, selling, and servicing base resins and additives.

26.541 Computer Applications in Plastics* (3-0)3 Problem solving in plastics engineering has been dramatically influenced by the computer and innovative software packages. This graduate course will focus on the application and development of software packages for engineering analyses of plastics processes.

26.543/4 Survey of Plastics Materials I & II (3-0)(3-0)6 Descriptive course centering on the historical development of polymeric systems, their synthesis, structure, properties, and applications. Included will be a brief discussion on the typical additives employed to make plastics molding compounds. Not open to B.S. Plastics Students.

26.545 Additives for Polymeric Materials* (3-0)3 Additives incorporated into polymers to modify processing and end-use properties: reinforcements, plasticizers, stabilizers, flame

retardants, colorants, biostats, blowing agents, anti-stats, impact modifiers, and processing aids.

26.546 Mixing in Plastics Processing* (3-0)3 Solids mixing, mixing in viscous fluids, admixing, concept and techniques of residence time distribution, continuous and batch processes, improvement of extrudate quality, scale-up and theory of similarity, dispersion and distributive mixing, mixing and heat transfer.

26.547 Analytical Methods in Plastics Processing* (3-0)3 Vector and tensor analysis, matrices and determinants, vector differential calculus, Laplace and Fourier transforms, power series, partial differential equations, introduction to numerical analysis. Use of the above techniques in plastics engineering calculations.

26.548 Numerical Methods in Plastics Processing* (3-0)3 Use of numerical methods in the solutions of problems concerning rheology, heat transfer, diffusion, and viscoelastic theory. Topics include solutions to ordinary differential equations, simultaneous linear equations, finite difference methods, finite element methods, plotting, linear regression, linear interpolation, curve fitting and optimization techniques.

26.552 Design of Polymer Processing Machinery* (3-0)3 Hydraulics, machine logic, drives, pumps, motors, heating barrel and screw combinations, mechanical design. Hydraulic and electrical control circuits development. A semester project is required.

26.553 Polymers in Medicine I* (3-0)3 The concepts necessary to analyze the use of materials for implants and biomedical devices will be introduced. The role of surface and bulk material properties in the use of materials in soft tissue, blood and hard tissue will be examined.

26.554 Polymers in Medicine II* (3-0)3 Prerequisite: Polymers in Medicine I. Design and test methods for polymeric based medical devices will be examined for vascular grafts, artificial hearts, reconstructive surgery, orthopedic applications, controlled release devices and hybrid artificial organs.

26.555/6 Rheology and Characterization Practicum I & II (2-3)(2-3)6 Practical review of theorectical concepts of rheological measurements with practical applications of experimental techniques. Emphasis will be on the viscoelastic properties of polymer solutions, melts, and solids with correlation with theoretical dynamic mechanical behavior.

26.557 Composites Fabrication I* (2-2)3 Introduction to resins and reinforcements. Fabrication of thermoset composites. Hand lay-up, vacuum bagging, autoclaving, compression molding, rheological testing. Design concepts, product management, quality control.

26.558 Composites Fabrication II* (2-2)3 A continuation of 26.557 with emphasis on a semester project on design, processing, and economics of composites.

26.559 Elements of Packaging* (3-0)3 Packaging methods, materials, and container designs. Analysis of container manufacturing methods for paper, plastics, cans, cardboard and their specific properties.

26.563/4 Materials Seminar I and II (1-0)1 Individual reasearch and presentation in the field of plastics materials.

26.565 Engineering Polymers (3-0)3 Prerequisite: 26.543/4. A continuation of 26.543/4 with emphasis on the engineering, high performance, and specialty polymers, including nylons, acetals, acrylics, polycarbonates, polyaryl sulfones, LCP's, polyimides, fluoropolymers, and engineering alloys/blends.

26.566 Polymeric Material Systems Selection* (3-0)3 Prerequisite: 26.201/2/301 or 26.543/4/565. This upper-level undergraduate/graduate bridge course investigates the selection processes to be followed in screening material candidates, and specifying a material of record. Emphasis is placed on prioritizing performance requirements, contrasting potential candidates, reviewing processing demands, and post-fabrication schemes. The course will be based on actual case studies.

26.567/568 Dynamic Mechanical Properties of Polymers I & II (3-0)3 This graduate course will focus on the principles, experimental techniques, and investigative strategies for characterizing the viscoelastic behavior of polymers using dynamic mechanical techniques. Lectures and demonstrations will review the methodology for identifying the important rheological characteristics of polymeric solution, melts, and solids. Comparisons with other, more traditional practices will be established for quality of data, sensitivity to macromolecular architecture, and components of materials engineering. Dynamic Mechanical Properties of Polymers II is a continuation of the 26.567 introductory course.

26.571/2 Plastics Process Engineering Laboratory I & II (0-3)(0-3)2 Laboratory study of the interaction between process variables and materials in extrusion, injection molding, blow molding, thermoforming, compounding and mixing.

26.573/4 Physical Properties Laboratory I & II (0-3)(0-3)2 Measurement of mechanical properties in tension, compression, shear, and flexure; dielectric constant and dissipation factor; thermal behavior under stress; melt rheology.

26.575 Biomaterials (3-0)3 A survey of materials for applications in biomedical applications with an emphasis on a broader view of the field than studies limited to the properties of different metals, ceramics, plastics, elastomers, textiles, and composites employed as body implants.

26.576 Advanced Mold Design (3-0)3 A continuation of 26.376. Selected topics include new materials of mold construction, machining operations, developments in rapid tooling, methods of mold repair, new developments in hot runners, and special tooling. An advanced treatment will be presented on mold filling, heat transfer, and freeing mechanisms.

26.577/8 Plastics Process Engineering I & II (3-0)(3-0)6 Fundamental principles of polymer processing, the conversion of polymeric materials into useful articles. Correlation between process variables, material characteristics and part design.

26.579 Problems in Biomaterials — Directed Studies (3-0)3 Selection of a current biomaterial problem of interest by the individual student, examination of pertinent literature to determine present knowledge in the area, formulation of an approach to resolve or clarify the issues involved, and (time permitting) work towards the solution of the selected problem.

26.580/1 Polymer Science I and II (3-0)(3-0)6 An introductory course in polymer science and technology including basic classification and molecular structures, synthesis, solution properties and molecular weight determination, solid-state properties including both the amorphous and crstalline states, degradation mechanisms, polymer reactions, network formation, copolymerization and blends/alloys. This class is only offered in the evenings and may be used as a substitute by Plastics Engineeering majors for 97.503/504.

26.582/569 Design Seminar I and II (1-0)(1-0)2 Individual research and presentation in the field of plastics design.

26.583 Advanced Research Methodology* (3-0)3 A systematic evaluation of the techniques used in efficient research and development. Experimental data are analyzed and plotted using a mathematical approach. Creative thinking, problem solving and student presentation of data are stressed. Extensive reading of research papers, their analysis and defense of the analysis is required.

26.584/570 Processing Seminar I & II (1-0)(1-0)2 Individual research and presentation in the field of plastics processing.

26.585/6 Computer Aided Engineering and Design* I & II (3-0)(3-0)6 Prerequisite: 22.421 Design of plastic components and molds. Finite element programs to perform linear and nonlinear stress analysis. MOLDFLOW program for detailed mold design.

26.590 Survey of Intellectual Property (3-0)3 A review of patents, trademarks, copyrights and their application for protection of technology in the pastics industry. Other topics to be considered will be employee rights/non-competition agreements, foreign protection, and technology licensing.

26.595 Thermoplastic Elastomers (3-0)3 A comprehensive review of thermoplastic

elastomer (TPE) technology. Physical and chemical nature of the various classes of TPE's will be considered with emphasis on mechanical and rheological properties relevant to engineering applications.

26.598 Smart Polymers (3-0)3
A contemporary course detailing recent advances in polymeric materials that respond to an excitation by changing one or more of their physical properties. Specific topics include electrorheological and magnetorheological fluids, smart gels, positive thermal coefficient, electrospinning of fibers, shape memory alloys, piezoelectric polymers, and polymers for nonlinear optical applications.

26.599 Rapid Prototyping (3-0)3
Survey of the rapidly expanding technology field of rapid prototyping. Technologies to be considered include stereolithography, laminated object manufacturing, selective laser sintering, fused deposition modeling, and solid ground curing.

26.600/1 Education With Industry (3-0)(3-0)6 A cooperative educational effort with local plastics firms to provide students with practice oriented, hands-on training in production and manufacturing operations. Specifically designed for high school students and community college instructors.

26.743/6 Master's Thesis Research (0-9)3/(0-18)6 Individual research projects in plastics.

26.753/6/9 Doctoral Research and Dissertation (0-9)3/(0-18)6/(0-27)9
Individual research projects in plastics.

26.763/6/9 Continuing Graduate Research (0-9)3/(0-18)6/(0-27)9
Individual research projects in plastics.

*These courses are given only when there is sufficient demand.

DEPARTMENT OF WORK ENVIRONMENT

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Graduate Programs in Work Environment

Our emphasis is on preventing work-related illnesses, injuries, and deaths simultaneous with the promotion of the health and safety of both the workers and the general environment. Our curriculum focuses on identification, quantitative assessment, and prevention of chemical, ergonomic and other hazards to human health. Our concern with the work environment also encompasses the psychosocial stressors of the workplace that affect workers' health and job performance and the employer's productivity.
Recognizing the complexity of work environment problems and the need for prevention, the solutions we seek attempt to integrate the scientific, political, economic and social approaches.

Master of Science

The Master of Science program will prepare graduates with the master's degree to become prevention practitioners in one of five work environment disciplines (industrial hygiene, occupational ergonomics, occupational epidemiology, work environment policy, and cleaner production and pollution prevention). The Department offers a program leading to the master's degree with thesis option or non-thesis option (project or capstone course). Candidates choosing the thesis option are guided by a committee of three faculty members.

Combined Bachelor's and Master's Degree Program

The department participates in the University's effort to encourage outstanding graduate students to begin study toward an advanced degree while still undergraduates. Arrangements are possible for joint programs that combine a bachelor's degree in one of the other departments in the College of Engineering with a master's degree in the Department of Work Environment. Such arrangements are made for eligible students after discussions with graduate coordinators in both departments (see eligibility requirements in catalog section on combined degrees).

Doctor of Science

The doctoral program is designed to prepare research scientists with a strong orientation towards prevention and applied research. The program includes advanced graduate work in each of the five work environment concentrations (industrial hygiene, occupational ergonomics, occupational epidemiology, work environment policy, and cleaner production and pollution prevention). Candidates will, under the direction of a faculty advisor and dissertation committee, carry out original research culminating in a doctoral dissertation.

MASTER OF SCIENCE DEGREE PROGRAM

Admission Requirements

Successful applicants will meet the standards of the Graduate School of the University of Massachusetts Lowell and, in addition, will have demonstrated the ability and motivation necessary for independent creative work and an interest in issues of the work environment. Strong preference will be given to candidates with both a quantitative academic background and experience in industry, government or health care. At the same time, the faculty of the Department of Work Environment believes that the program (and the profession) is strengthened by admitting students from a wide diversity of backgrounds, and therefore students with non-traditional educational or work backgrounds will be considered carefully.

To be admitted, an applicant to the Master of Science degree program in Work Environment must have a baccalaureate degree or its equivalent from an accredited institution. The applicant must show an acceptable grade point average (3.0) and demonstrate preparation in quantitative sciences. It is expected that the great majority of applicants will provide evidence of completing at least a year of physics, calculus and organic chemistry at the college level. Preference will be given to applicants with such preparation. No applicant will be accepted without evidence of strong preparation in mathematics, and a semester in statistics is strongly recommended for all concentrations. Applicants applying to the epidemiology concentration must have completed at least one semester of calculus as well as an undergraduate statistics course. Applicants intending to study ergonomics must have completed at least one semester of college physics and one semester of calculus. Applicants who wish to pursue industrial hygiene must have completed at least one semester each of calculus, physics, and organic chemistry. The G.R.E. Aptitude Test is required for all applicants unless they already hold a graduate degree and the Graduate Coordinator requests that the Graduate School waive the requirement.

Academic Advisor

Each graduate student admitted into the Department of Work Environment will be assigned an academic advisor who will assist in the selection of courses and who will develop, with the student, a program which will meet the needs and requirements for the desired concentration. For a master's degree candidate who selects the non-thesis option, the academic advisor will supervise the advanced research project.

Master's Thesis

A student selecting the thesis option will arrange, through the academic advisor, to have a three-member faculty committee appointed at the time a thesis proposal is submitted. At least two of the committee members shall be from the student's area of concentration. The committee is responsible for approval of the proposal.

The report on the research work will then be performed primarily under the supervision of the academic advisor. The thesis must be prepared in appropriate form and be presented to the thesis committee for final approval. The student is required to give an oral defense of the thesis before the committee and other faculty members. The completed thesis must conform to the format specified in the "Thesis Guide", available from the Graduate School.

Master's Project

The project will consist of a scholarly investigation, such as a review, report, synthesis or design in the student's field resulting in a written document. Each project is awarded three credits and is intended to be completed within the time limit of one semester. If the work for a project is not completed by the end of the semester, the instructor will give the student a grade of "I" which is to be treated the same as an incomplete for a regular course.

Capstone Course

This three-credit course (19.600) is designed to provide students with the opportunity to examine a problem in depth and propose a solution to the problem. The product will be a term paper and a public presentation of the proposed approach. Students will be assigned a

faculty member to serve as a consultant to the process of developing a solution, although the faculty's role will be to provide guidance and general advice, not detailed directions.

Course Requirements for the Master's Degree

A core of 15 credits is required of all students in the master's degree program. An additional 30 credits is required for each of the concentrations for students with no prior experience. Requests for waiver of any specific course requirements will be considered on a case- by-case basis and will depend on documentation of equivalent course work at another institution, or upon satisfactory evidence of advanced professional standing.

Core Courses:

19.500	Intro. to Work Environ	3
19.503	Toxicology and Health	3
19.525	Intro. to Industrial Hygiene/Ergonomics	3
19.575	Intro. to Biostatistics & Epidemiology	3
19.600	Work Environment Capstone	3

Areas of Concentration Occupational Ergonomics:

Ergonomics provides the scientific basis for optimized design of the work environment compatible with the capabilities and limitations of the working population. An ergonomist is trained to recognize, evaluate, and control hazards in the work environment that result from a poor fit between the worker and the workplace; these hazards may result in acute injury, chronic musculoskeletal disorders, or mental/psychosocial "stress." The physical demands of machines, tools, and work methods must accommodate the range in size, strength, mobility, and endurance of the workforce. Information flow must be structured so that the worker can process and respond appropriately without being mentally overstressed to the degree that errors result. Job content and work organization should be designed to optimize skill utilization and learning, physiological and psychological well-being.

The concentration in Ergonomics is designed to develop an understanding of human anatomy, physiology, and psychology, of industrial hygiene and epidemiology as well as modern manufacturing technology and work organization. It provides a multidisciplinary background in these basic areas, as well as their application to the practical problems in ergonomics that are encountered in industrial and service work environments.

The following courses are required in addition to the core:

19.531/ 19.532	Occupational Biomechanics Lab	3
19.542	Human Factors	3
19.638	Methods in Work Analysis	3
Electives		21

The curriculum allows the Ergonomics students to choose 21 credits in electives. These electives will be selected by each student in accordance with her/his background, interests, and career goals. It is expected that the set of chosen electives will represent a coherent "track" or "option" within the concentration. These choices should be thoroughly discussed with the advisor. Options include a joint concentration with Industrial Hygiene; "general practice" in safety and ergonomics; musculoskeletal disorders; and psychosocial strain/work organization.

Industrial Hygiene

Industrial hygiene is concerned with the protection of worker health through the prevention of occupational illness. Industrial hygienists accomplish this goal through the recognition, evaluation, and control of chemical, physical, and ergonomic hazards in the work environment. The control of such hazards allows the worker to perform his/her job in a productive manner, free from the debilitating effects of work-related illnesses.

Graduates will be prepared in the initial diagnosis of exposure problems in industrial settings. This will include awareness of work organization issues and ergonomic risk factors. The graduate will also be prepared in developing a sampling and evaluation strategy to characterize the extent of the problem, in the proper field collection and laboratory techniques to measure exposures, in the determination of the controls needed to solve the identified exposure problems, and in the theoretical and practical design aspects of such controls including toxics use reduction.

The following courses are required in addition to the core:

19.514	Aerosol Science	3
19.517	Physical Agents: Evaluation & Control	3
19.518	Engineering Controls & Personal Protective Equip.	3
19.540	Design for Injury Prevention	3
19.610	Exposure Assessment	3
19.617	Measurement of Airborne Contaminants/Lab	3
19.625	Field Evaluations/Lab	3
Electives		9

The curriculum allows the Industrial Hygiene student to choose 9 credits in electives. Every choice should be thoroughly discussed with your advisor.

Epidemiology

Epidemiology is the study of the distribution and determinants of disease in human populations. Today's occupational epidemiologist is called upon to identify previously unsuspected diseases caused by exposure to hazards in the work environment, to assess the health risks of new technologies, to recommend a scientific basis for the setting of occupational standards to protect worker health, and to evaluate the ability of control technologies to limit health risks. Epidemiology is a rapidly evolving discipline using increasingly sophisticated statistical methods to quantify the risks of low level, long-term exposures to hazardous physical and chemical agents. The field is highly interdisciplinary, drawing on physiology, toxicology, biostatistics, industrial hygiene and biomechanics.

To meet the need for epidemiologists in industry, government and academia, the student in the epidemiology concentration will be trained in the full spectrum of epidemiologic methods, and will acquire the necessary background in the related fields of biostatistics, physiology, industrial hygiene, and ergonomics.

The following courses are required in addition to the core:

19.576	Intermediate Biostat. & Epidemiology	3
19.610	Exposure Assessment or:	
19.638	Methods of Job Analysis	3
19.674	Multivariate Methods in Epidemiology	3
19.687	Quantitative Models in Env. Health Assess.	3
19.682	Occupational Epidemiology	3
19.683	Risk Assessment	3
19.733	Research Project	3
Electives		9

In addition to the above requirements, students would choose three additional

3-credit courses in consultation with the advisor. The courses are expected to have some subject area coherence, but would not be otherwise defined. Some likely courses from which to choose might include:

19.690	Critical Reviews of Occupational Health Standards
19.685	Injury Epidemiology
19.684	Musculoskeletal Epidemiology
19.540	Design for Injury Prevention
19.675	Reproductive Epidemiology
19.542	Human Factors
19.643	Healthy Work Organization
19.634	Cardiopulmonary Effects of Work
19.725	Epidemiologic Theory

Work Environment Policy:

The policy analyst must understand the interaction between science (and scientific uncertainty) in occupational and environmental health, and the politics of the workplace setting. The fields of occupational and environmental health are integrated by the practical focus on actual workplace conditions: policy is based on the science; engineering and political economy provide the solutions.

The Work Environment Policy concentration will provide master's level education to graduates from a wide variety of backgrounds, including the social sciences and law, who wish to be administrators of occupational health and safety programs in the private and/or public sectors, or who wish to be policy analysts in agencies and organizations concerned with affecting environmental health and worker safety and health.

The following courses are required in addition to the core:

19.550	Environmental Law & Policy	3
19.558	Occupational Health Administration or:	
19.643	Healthy Work Organization	3
19.651	Work Environment Policy	3
19.683	Risk Assessment	3
Electives		18

The Policy student must take 18 elective credits derived from courses agreed upon by the advisor and student.

Cleaner Production and Pollution Prevention:

This specialization is one of the few programs of its kind in the country. It combines a working knowledge of the work environment in its core curriculum and an intensive study experience in the principles and techniques of production for sustainability. The sustainable production systems of the future must integrate economic performance with sound environmental policy and strong safeguards for workers and public health. Pollution Prevention or environmentally conscious manufacturing is characterized by sound management, creative and productive design, environmentally friendly products, waste minimization and work organizations that protect health while assuring economic returns.

The following courses are required in addition to the core:

19.550	Environmental Law & Policy	3
19.557	Toxic Use Reduction	3
19.625	Field Evaluations/Lab	3
19.651	Work Environment Policy	3
19.654	Labor and Technology	3
19.655	Economic Analysis	3
19.683	Risk Assessment	3
19.659	Cleaner Production Principles	3
Electives		6

The Cleaner Production student must take 6 elective credits derived from courses agreed upon by the advisor and student.

DOCTOR OF SCIENCE DEGREE PROGRAM

Admission Requirements

Doctoral training is built upon the substantial didactic training gained in the master's degree programs. To be eligible for admission to a doctoral program, an applicant will need to demonstrate appropriate undergraduate education with adequate preparation in quantitative sciences. For an applicant who has not obtained a master's degree in work environment or a related field, direct admission to the doctoral program will be possible but will require documentation that the equivalent course work has been completed. He or she will need to provide a minimum of three letters of reference attesting to the ability to perform advanced graduate work and to provide a written statement of career objectives and the relationship of doctoral training to those objectives. Evidence of academic ability must be provided in the form of undergraduate and graduate transcripts detailing an acceptable grade point average (generally a minimum of 3.0, with 3.5 in quantitative sciences). Performance on the Graduate Record Examination Aptitude Test must be at a high level. An applicant who already holds a graduate degree may request waiver of the G.R.E. requirement. Finally, a personal interview will be required in selected cases.

Academic Advisor

For a doctoral candidate, the primary responsibility for evaluating progress will rest with the student's academic advisor along with the Dissertation Committee. Upon matriculation, the student will be assigned an advisor in conjunction with the Graduate Student Coordinator and the student. The advisor must be from among the faculty of the Work Environment Program. Within one semester after completing the core courses, the student must identify a research topic. The advisor will assist the student in complying with all the university requirements in achieving eligibility for the degree.

Doctoral Dissertation

The doctoral dissertation will be based on a substantial body of original research carried out by the candidate. The selection of the research topic will be the responsibility of the student in consultation with the academic advisor. When the doctoral student has completed all course requirements for the doctoral degree, together, the student and advisor will propose to the Department Graduate Committee (DGC) a program and Dissertation Committee. Once approved, the Committee will meet at least as frequently as every six months to review the student's progress. The Committee will assess whether the student is making adequate progress toward completing the dissertation in the required years of study and will approve the dissertation. The student is required to give an oral defense of the dissertation before the Committee and other faculty members. The defense is open to the public.

Requirements for the Doctoral Degree

Degree requirements include: six to eighteen credit hours of courses beypnd the master's degree plus twelve to 24 credits of disseration research for a total of 30 credits. A student with a master's degree from another institution will need to show knowledge in all subject areas required for the equivalent Work

Environment master's degree from the University of Massachusetts Lowell. Courses will be selected to prepare each student in one major and two minor fields. The major field must include, at a minimum, six full courses (18 credits), and the minor fields, three courses (9 credits) each. Courses taken for the master's degree may be used to meet these requirements. There is no language requirement. The student will work with a doctoral program advisor to propose a set of courses to meet the requirements and to prepare a preliminary thesis proposal. The Graduate Committee will then approve the list of courses and the preliminary proposal.

Following approval of this preliminary program, the student will be eligible to take a written qualifying examination. The exam will be designed to test the knowledge in the major field. Upon meeting the course and written exam requirements, the student must pass an oral qualifying exam based on his or her written dissertation proposal. The dissertation will, in general, be in the form of three publishable manuscripts and will include an appropriate literature review and overview of the dissertation research.

Industrial Hygiene

Likely areas of research include exposure assessment, ventilation system design, aerosol science, chemistry of airborne contaminants, noise control, techniques for reducing the use of toxic chemicals, and respiratory protection. Required courses include at least one of the seminars in the series 19.611-620. A student will normally take two or more of these, depending upon the selected area of research.

Ergonomics

Examples of areas of doctoral research are field evaluation of ergonomic exposures and hazard surveillance, biomechanical modeling, psychophysical methods of work analysis, evaluation of control measure effectiveness, and technical and social factors in the reorganization of work. Required courses include one or more of the advanced seminars in the series 19.630-638, 19.610, 19.684, or 19.685. A student will ordinarily take two or more of these, depending upon the selected area of research.

Epidemiology

Required courses include: 19.690, a graduate course in mathematical statistics, one in pathophysiology, and additional advanced courses in epidemiology and biostatistics. Examples of areas of research in which doctoral work is encouraged include: respiratory epidemiology, injury epidemiology, exposure modeling for epidemiology, occupational disease surveillance, epidemiology and musculoskeletal disease, and occupational cancer epidemiology.

Work Environment Policy

Examples of areas of research encouraged for doctoral work are: Labor and technology, regulatory policy, occupational health and labor/management programs, economic aspects of risk assessment, health and safety impacts of new technologies, management of chemical information, toxics use reduction, and international health and safety.

Cleaner Production

Examples of areas of research in Cleaner Production include: materials accounting and chemical use reporting, assessment of the effectiveness of "third party" auditors in promoting pollution prevention, alternatives to risk assessment that encourage workplace redesign, and intergration of occupational health and pollution prevention.

COURSE DESCRIPTIONS

19.500 Intro to Work Environment (3-0)3 An overview course to be taken as the first or second course in the Master's program. Case studies are used to introduce students first to the hazard analysis methods, and second, to the prevention methods of each of the department's sub-disciplines. Interconnections between exposures and illness/accident development are reviewed at three levels: individual, work organization and society.

19.503 Toxicology and Health (3-0)3 Examines the effects of the major and chemical physical hazards in the modern work environment. Presents principles of toxicology as well as the toxicology of heavy metals, organic solvents, pesticides, harmful dusts, asphyxiants. Mechanisms of the effects on human physiologic systems are described along with the physiologic effects of ionizing radiation, heat stress, noise and repetitive trauma.

19.509 Hazardous Waste Worker Health and Safety (3-0)3 Presents appropriate approaches to protection from health and safety hazards encountered on chemical waste sites and regulation liability, medical surveillance, and waste control policies.

19.514 Aerosol Science (3-0)3 Prerequisite: Consent of Instructor for non-industrial hygiene majors. Basic properties of airborne particles, with particular regard to properties important to health. Includes basic properties of gas-borne particles, uniform particle motion, particle collection mechanisms, filtration, particle sampling, respiratory deposition, particle statistics, electrical properties, and optical properties. Course includes lectures and laboratory.

19.517 Physical Agents: Evaluation and Control (3-0)3 Prerequisite: 19.525; consent of Instructor except for designated majors. Physical hazards in the work environment include noise, vibration, heat and cold, and ionizing and nonionizing radiation. This course describes each of these hazards and presents the physics underlying their behavior, techniques used to evaluate exposure, and methods of control. Course includes lectures and laboratory sessions.

19.518 Engineering Controls and Personal Protective Equipment (3-0)3 Prerequisite: Consent of Instructor for non-industrial hygiene majors. Techniques for controlling exposure to airborne contaminants. Basic controls include toxics use reduction, ventilation, isolation, administrative controls, and personal protective equipment. The course consists of lectures, laboratory, and field sessions.

19.525 Introduction to Industrial Hygiene and Ergonomics (3-0)3 A survey course covering introductory topics in ergonomics and industrial hygiene. Ergonomics topics include work measurement, anthropometry, biomechanics, psychosocial stress and work reorganization, special emphasis is placed on the recognition and control of work-related musculoskeletal disorders. Industrial hygiene topics will cover the identification, measurement, and control of chemical and physical hazards in the work environment including principles of air sampling and analysis, ventilation and other control technologies, and the use of personal protective equipment with special attention to respiratory and hearing protection.

19.530 Ergonomics and Work (3-0)3 An overview of the scientific basis for design of the workplace to optimize physical and mental interaction of workers with machines, tools, and work methods. Topics include work measurement, anthropometry, biomechanics, work physiology, cumulative trauma disorder and information presentation and processing.

19.531 Occupation Biomechanics (3-0)3 Prerequisite: 19.525 or consent of Instructor. The anatomical and physiological basis of human motor capabilities. Quantitative models are developed to explain muscle strength performance, motion control, physical fatigue, and acute and chronic musculoskeletal trauma, particularly static link models of lifting

and other manual activities. Application to the evaluation and design of various tasks and occupations.

19.532 Laboratory in Occupational Biomechanics (0-3)3
Prerequisite: Concurrent or prior enrollment in 19.531. A laboratory presentation of the biomechanical basis for understanding and predicting human motor capabilities using bioinstrumentation. Computerized data acquisition, electromyography and load cells for strength measurement are examples of the equipment used in this lab. Particular emphasis is placed on the evaluation of occupational activities.

19.537 Work Physiology (3-0)3
The physiological responses of the cardiopulmonary system to whole-body and local exertion. Physical fatigue, contribution of exertions to heat stress, and psychophysical limits of work tolerance. Quantitative models will be used to estimate metabolic costs of tasks frequently performed.

19.540 Design for Injury Prevention (3-0)3 Design of tools, equipment, and environment for the elimination or control of occupational safety hazards (industrial machinery, slips/falls/ climbing, enclosed spaces, robotics/ automated systems, etc.). Anthropometric analysis, hazard analysis, systems safety, accident investigation and reconstruction.

19.541 Construction Occupational Safety and Health (3-0)3 A seminar covering various topics in construction occupational health and safety. Topics to be covered include: OSHA and Regulation, Fatalities, Fall Protection and Rigging, Confined Spaces and Trenches, Electrical and Hand Tool Safety (Lockout/Tagout), Job Hazard Analysis, Noise, Ergonomics and the Prevention of Musculoskeletal Disorders, Industrial Hygiene and Exposure to Asbestos, PNOC, Diesel and Lead, and Construction Safety Culture. Outside speakers (many will be safety representatives from construction contractors or other professionals in the construction industry) will be brought in to discuss these topics.

19.542 Human Factors (3-0)3
Prerequisite: 19.525 or consent of Instructor. The functional processes of human systems in the workplace that affect psychosocial health and productivity. Review of associations between work design principles and effects on human well-being, learning, and performance. Human perceptive, cognitive, metabolic, and social-psychologic limitations. Human-machine interactions affecting "stress" and learning at the level of individuals and of groups. Introduction to "healthy" job redesign, "conducive production," and measurement strategies. Principles applied through practical design problems.

19.550 Environmental Law and Policy (3-0)3 Survey of relevant environmental laws and their application to public policy. A framework for understanding environmental politics will be developed. This course is also offered in the Environmental Sciences program as 18.522.

19.557 Toxic Use Reduction (3-0)3 Toxic Use Reduction (TUR) is a new approach to hazardous waste management and environmental protection. Rather than addressing chemical contamination as waste (after its generation), to be managed through permits and emission regulations, TUR focuses on chemicals while still in production. In Massachusetts, firms are required to prepare plans demonstrating how they will reduce or eliminate the use of toxic chemicals. The course is organized as a set of discussions and case studies from the "real-life" program.

19.558 Occupational Health Administration I (3-0)3 An introduction to management practices for occupational health and safety specialists. Topics include general program management subjects (business policy and corporate organization, human resources management, accounting and budget management). Special attention will be given to program administration in the public sector. In addition, subjects particularly relevant to occupational health practitioners, such as "right to know", worker training and health and safety committees will
be covered.

19.561 Occupational Health Administration II (3-0)3 Prerequisite: 19.558. This course will analyze the elements of an industrial program to educate workers and supervisors in hazard communication including applicable "right-to-know" laws, and administrative issues concerning chemical, ergonomic, and physical hazards. In addition, the elements of an in-plant toxics use reduction program will be presented describing the activities of toxics reduction planners.

19.563 Risk Communication & Management (3-0)3 Prerequisite:19.551. Development of the methods and programs needed for in-plant planners addressing reduction in use of toxic materials, and amelioration of ergonomics and physical hazards. The elements of in-plant risk communication will emphasize effective worker notification of the attendant occupational risks and the evaluation of the impact and effectiveness of communication efforts.

19.575 Introduction to Biostatistics and Epidemiology (3-0)3 Provides an introduction to the principal quantitative methods for assessments of the work environment. Topics include: probability theory, the normal distribution, Gaussian statistics, linear regression, epidemiologic study designs, causal inference in epidemiology, bias, and confounding.

19.576 Intermediate Biostatistics and Epidemiology (3-0)3 Prerequisite: 19.575 Provides a more advanced examination of quantitative methods for assessment of work environments. Topics include standardization, precision and validity, and second consideration of bias, confounding, study design, and multivariate analysis of epidemiologic data.

19.599 Work Environment Seminar Prerequisites: Enrollment in Department M.S. or Sc.D. program. Weekly seminar presenting current topics of research or applications importance in the field. The seminar will be presented by faculty and invited guests.

19.600 Work Environment Capstone (3-0)3 Prerequisites: Completion of masters curriculum. The course is designed to provide students with the opportunity to examine a problem in depth and propose a solution to the problem. The product will be a term paper and a public presentation of the proposed approach. Students will be assigned a faculty member to serve as a consultant to the process of developing a solution, although the faculty's role will be to provide guidance and general advice, not detailed directions.

19.610 Exposure Assessment (3-0)3
Prerequisite: 19.525; consent of Instructor except for designated majors. Concepts of quantification of occupational exposures (chemical and physical hazards) for purpose of correlating health effects with exposures. Topics discussed include reasons for conducting exposure assessment, sampling methods, sampling strategies (for epidemiology, compliance, control), and statistical considerations. Principles are illustrated through a series of case studies.

19.611 Physical Properties of Aerosols for Exposure Control (3-0)3 Prerequisite: 19.514. A seminar covering aspects of aerosol science not discussed in 19.514 but necessary for the completion of research projects involving aerosols. Topics covered include the electrical, thermal, and optical properties of aerosols, particle agglomeration, evaporation and condensation, and the generation and measurement of test aerosols. Course will consist of lectures and laboratory sessions.

19.612 Industrial Hygiene Exposure Data Analysis (3-0)3 Prerequisite: 19.512. An advanced seminar covering industrial hygiene strategies for the assessment of exposures related to health effects and statistical sampling strategies for the collection and analysis of exposure data. Topics include methods to evaluate the distribution of exposure data, sources of exposure variability, partitioning variability, developing physical models of exposure, and multivariate modeling of exposure measures.

19.613 Design and Evaluation of Ventilation Systems (3-0)3 Prerequisite: 19.518. A seminar intended for students pursuing research involving industrial ventilation system design and evaluation. It covers material not included in 19.518, such as recent theoretical models which describe system performance, design of systems for high-temperature operation, trouble-shooting techniques, and advanced instrumentation techniques. Course consists of lectures and laboratory sessions.

19.617 Measurement of Airborne

Contaminants (2-1)3 Prerequisite: 19.510, 19.514 consent of Instructor for non-industrial hygiene majors. Sampling and analysis methods used in the evaluation of occupational exposures to aerosols, gases, vapors and microorganisms. Direct reading instrumentation, calibration and data processing. Integrated sampling methods and chemical analysis of organic and inorganic compounds will be covered in class and lab.

19.620 Advanced Exposure Assessment (3-0)3 Prerequisite: 19.610. An advanced seminar covering exposure assessment for studies of acute and chronic respiratory disease, pharmacologic modeling for exposure assessment and the design of models to evaluate the role of production process factors in determining workplace airborne exposures. The course assumes a prior background in epidemiology and biostatistics as well as industrial hygiene and toxicology.

19.625 Field Evaluations in Work Environments and Lab (3-0)3 This course provides the work environment professional with a systematic method of evaluating chemical, ergonomics and work organizational hazards in the field. Formal walkaround inspections are conducted in local industries and formal reports are prepared. A laboratory for quantitative measurements of chemical and ergonomic risk factors is an integral part of the course.

19.630 Research Design for Ergonomics (3-0)3 Prerequisite: 19.525 or consent of Instructor. Procedures for conducting research on ergonomics (human factors, biomechanics, etc.). Experimental design alternatives, field research, survey research, considerations of data collection and reduction, sequential design procedures, and ethical use of human subjects.

19.632 Advanced Biomechanics (3-0)3 Prerequisite: 19.531 and Permission of Instructor. A course in advanced biomechanical modeling methods, covering three dimensional static models, optimization methods and dynamic models. Special emphasis will be placed on biomechanical models of the hand. Time will also be dedicated to reviewing current developments in the scientific literature.

19.634 Cardiopulmonary Effects of Work (3-0)3 Prerequisites: 19.525, 19.537 and 19.570, or consent of Instructor. A seminar reviewing current developments in the scientific literature on work physiology and occupational stress, including both experimental research and epidemiology of cardiovascular and pulmonary disease.

19.638 Methods in Work Analysis (3-0)3 Prerequisite: 19.500 or 19.530, 19.525 or consent of Instructor. Criteria for selection of an approach to ergonomic job analysis depend on the combination of exposures (micro- and macro-level ergonomic stressors) observed to be present as well as the analytical goal. Many ergonomic analysis techniques are based on traditional industrial engineering approaches (time-motion study and work sampling), applied to the identification and evaluation of potential risks to workers' health. A variety of methods, both observational and instrumentational, will be discussed; laboratory sessions will permit hands-on application of several of these for critical evaluation.

19.639 Advanced Work Measurement (3-0)3 Prerequisite: 19.638. This is an advanced seminar to evaluate and critique state-of-the-art ergonomic analysis methods, including some still under development.

19.643 Healthy Work Organization Design (3-0)3 Prerequisite: 19.525 or consent of Instructor. Rationales for prevention; determinant of job change feasibility, classic and alternative work organization theories, alternative productivity conceptions, health and growth assessment strategies, conducive work processes, work-group based re-design processes, communicative and network-oriented processes, organization-level change process, product redesign, occupational and political strategic issues.

19.650 Advanced Topics in Risk Assessment/Risk Perception (3-0)3 This course sets issues of risk assessment and risk perception in a social-psychological framework. Topics will include analysis of cognitive and non-cognitive approaches to risk; worker "subjective" measures of exposure; bureaucratic uses of risk assessment; risk communication; the public health approach to risk; and others.

19.651 Work Environment Policy: I (3-0)3 This course provides an overview of occupational safety and health policy in the U.S. It focuses on the legal context, especially on OSHA, but also provides an analytical framework for examining the role of social, economic and political factors in the recognition and control of occupational hazards.

19.653 International Occupational Health & Safety (3-0)3 Prerequisite: 19.551. A comparative analysis of occupational health and safety in developed countries. Descriptions and needs of developing countries in occupational health will be reviewed. Issues covered for both will include: Surveillance and definition of needs; descriptions of interventions; and programs for primary and secondary prevention activities.

19.654 Labor and Technology (3-0)3 This course examines the broader issues of the impact of technology on the work environment and on workers. Topics include technology and craft work, Taylorism and the development of mass production methods, labor in the "factory of the future", skill-based automation, shop floor programming, and other issues in technology policy.

19.655 Economic Analysis for Work Environment (3-0)3 This is a course in applied microeconomics, focusing on benefit/cost analysis, cost effectiveness analysis and other tools of engineering economic analysis. These are approaches essential for private sector as well as government work environment policy. Students will learn the application, as well as the criticism, of economic analytical techniques and will write a term paper employing the methods.

19.656 Worker's Compensation (3-0)3 Prerequisite: Permission of instructor. This seminar will review 1) the history of workers' compensation in the United States, 2) the basic outline of current workers' compensation systems, 3) leading issues in workers' compensation "reform" efforts, 4) the effectiveness of workers' compensation in dealing with occupational disease as well as injuries, 5) the interface between workers' compensation and health care reform. Cross-national experience will also be examined.

19.657 Gender Difference at Work (3-0)3 Offered by Department of Regional Economic and Social Development. This team taught course explores differences in women's and men's work in both the paid and unpaid labor force, including the household. Issues covered include differences in labor force participation, occupations, earnings, career ladders, health and safety, and technology. The major explanations offered by social scientists for the inequalities will be examined for their relevance. Strategies for change will be explored. The importance of class, ethnic/racial, and native-born versus immigrant status is fully integrated throughout the course. This course is designed to be relevant for both graduate students and upper-level undergraduates in a variety of disciplines.

19.659 Cleaner Production (3-0)3 Prerequisite: 19.557 or Permission of Instructor. This course will explore the rapidly expanding developments in cleaner production methods and policies. The course will focus on new directions in environmentally conscious manufacturing and product design in Europe. The subject will cover topics ranging from European demonstration projects, environmental auditing, cleaner technology assessment, eco-efficiency models, water and energy conservation, sustainable product design, eco-design and life cycle assessment, product take-back and extended product life, full cost accounting, industrial ecology, environmental management systems and ISO 14000. Special emphasis will be given to new information data sources and an introduction to new cleaner production methods software.

19.674 Multivariate Methods in Epidemiology (3-0)3 Prerequisites: 19.576 or consent of Instructor. The course is an in-depth study of multivariate models for both discrete and continuous outcomes. Topics include: multiple linear regression, logistic regression, and proportional hazards models. Covers methods of checking for violation of underlying assumptions, the construction and

interpretation of dummy variables, problems of model selection for causal inference and comparison of alternative models.

19.677 Reproductive Epidemiology (3-0)3 Prerequisites: 19.575 or consent of Instructor. A course on both the methods and content of research on the reproductive health risks of the work and general environments. Includes a review of reproductive physiology and embryology. Discusses the problems and strategies of collecting reproductive histories, the use of biologic markers of reproductive status and the approaches to analysis of maternal and fetal outcomes.

19.678 Occupational Respiratory Disease Epidemiology Prerequisites: 19.575 or consent of Instructor. Advanced course on the methods and content of research on occupational respiratory disease with focus on the appropriate use of spirometry, symptom questionnaires, and chest radiography in cross sectional and longitudinal studies. Reviews pathophysiology, prevalence, latency considerations and diagnosis of both acute and chronic respiratory disease caused or exacerbated by work. Special attention is devoted to the impact of the healthy worker selection effect in respiratory epidemiology studies.

19.680 Introduction to SAS (1-0)1 Prerequisite: Permission of Instructor. This course is designed for researchers who will be doing data analysis using SAS. No prior programming experience is necessary, though familiarity with and general experience in use of a PC (DOS and Windows) is required. The course covers topics including: basics of SAS, reading raw data and existing SAS data sets, modifying data, combining data sets, basic statistical procedures, sorting, summarizing, and printing data.

19.682 Occupational and Environmental Epidemiology (3-0)3 Prerequisite: Consent of instructor or 19.570. A course covering both the content and methods of occupational and environmental epidemiology. The students will read and critique numerous studies in the field, and learn the particular methods and difficulties of conducting epidemiologic studies in the work environment. Key concepts include the standardized mortality ratio and proportional mortality ratio, exposure assessment for epidemiology and the healthy worker effect.

19.683 Risk Assessment in Workplace and Environment (3-0)3 Prerequisites: 19.525, 19.575 or consent of Instructor. This course will review both the methods and policy implications of risk assessment in the development of occupational and environmental standards. Students will conduct risk assessments on real problems, and study important cases in which these methods have been used in setting public policy.

19.684 Epidemiology of Musculoskeletal Disease (3-0)3 Prerequisites: 19.525, 19.575. An advanced course on methods and content of research on work-related musculoskeletal disorders. Reviews pathophysiology, prevalence, latency considerations, and diagnostic methods. The key literature is examined with attention to study design, quality of exposure assessment, control of bias and adequacy of statistical analysis. Screening and surveillance are also covered.

19.685 Epidemiology of Acute Injury in the Workplace (3-0)3 Prerequisites: 19.525, 19.575. A seminar covering both the methods and content of studies of the risk factors for acute physical injury in the work environment. Following a review of current knowledge on the subject and models of injury causation, the course will focus on the collection of injury data, measurement of exposure to injury risk factors, the design of surveillance systems, and suitable statistical analysis methods. Students will critique the current literature in the field.

19.687 Quantitative Models for Environmental Health Assessment (3-0)3 Prerequisites: 19.576 or consent of Instructor. In this seminar readings, discussion, group work and computer exercises are used to gain an understanding of how certain kinds of quantitative models work. Emphasis is placed on the underlying assumptions of these models, and on gaining an intuitive understanding of the most common modeling procedures. The types of models covered will be those most important to current research and policy in environmental health, including ordinary least squares, the method of maximum likelihood, Monte Carlo simulation, and systems of ordinary difference equations. There will be a diverse set of readings, frequent computer exercises to be worked either individually or in groups, and a final project. Facility with Excel or an analogous spreadsheet program will be assumed.

19.690 Critical Review of the Occupational Health Regulations (3-0)3 Prerequisites: 19.525, 19.575. Course designed to explore the practical applications of epidemiologic methods to the setting of actual standards. Students gain experience in distinguishing minor from major design and analysis flaws. Course is presented as a seminar with four case studies and problem analysis.

19.702 Independent Study in Industrial Hygiene (1-0)1 Advanced topics in industrial hygiene, exposure assessment or exposure control not offered in the regular curriculum. Topics may vary from year to year.

19.704 Independent Study in Ergonomics (1-0)1

19.705 Supervised Teaching - WE (0)

19.706 Independent Study in Work Environment Policy (1-0)1

19.708 Independent Study in Occupational Epidemiology (1-0)1

19.711 Independent Study Industrial Hygiene (3-0)3

19.712 Independent Study in Industrial Hygiene (2-0)2 Prerequisites: Specified at time of offering. Advanced topics in industrial hygiene, exposure assessment or exposure control not offered in the regular curriculum.Topics may vary from year to year.

19.713 Independent Study in Ergonomics (3-0)3

19.714 Independent Study in Ergonomics (2-0)2 Prerequisites: Specified at time of offering. Advanced topics in biomechanics, work physiology, occupational safety or human factors not covered in the regular curriculum. Content may vary from year to year.

19.715 Independent Study in Work Environment Policy (3-0)3 Prerequisites: Specified at the time of offering Advanced topics in work environment policy, risk perception, risk communication and management, regulatory affairs or labor-management programs not covered in the regular curriculum. Content may vary fromyear to year.

19.716 Independent Study in Work Environment Policy (2-0)2

19.717 Independent Study in Occupational Epidemiology (3-0)3 Prerequisites: Specified at the time of offering. Advanced topics in occupational epidemiology, design and confounding, exposure-response modeling, or surveillance not covered in the regular curriculum. Content may vary from year to year.

19.718 Independent Study in Occupational Epidemiology (2-0)2

19.719 Independent Study in Cleaner Production (3-0)3

19.720 Independent Study in Cleaner Production (2-0)2 Prerequisites: Specified at time of offering. Advanced topics in clean production, pollution prevention, and environmental protection efforts. Not offered in the regular curriculum. Topics may vary from year to year.

19.721 Selected Topics: Industrial Hygiene (3-0)3 Provides an opportunity for Industrial Hygiene students to integrate previous course works into a field project which involves identification, measurement, control and policy aspects. A research project is an alternative to the practicum for students who wish to use a research methodology to investigate some aspects of Industrial Hygiene.

19.723 Selected Topics: Ergonomics (3-0)3

19.725 Epidemiologic Theory (3-0)3

19.727 Selected Topics: Epidemiology

19.729 Selected Topics: Cleaner Production

19.731 Industrial Hygiene Practicum (3-0)3 A directed program of industrial hygiene field experience with a local industry or government agency, required of all master's degree candidates electing the non-thesis option in the industrial hygiene concentration.

19.733 Master's Project in Work Environment (3-0)3 Advanced research project required of all master's degree candidates in the ergonomics, industrial hygiene, occupational epidemiology and work environment policy concentrations.

19.743 Work Environment Master's Degree Thesis (3-0)3
19.746 Work Environment Master's Degree Thesis (6-0)6 Prerequisites: Minimum 15 credit hours of graduate courses at an acceptable level; approval of a written proposal outlining proposed research work.
19.753 Work Environment Doctoral Dissertation (3-0)3
19.756 Work Environment Doctoral Dissertation (6-0)6
19.759 Work Environment Doctoral Dissertation (9-0)9 Prerequisites: Minimum of 18 semester hours of graduate courses at an acceptable level; approval of a written proposal outlining the extent and nature of proposed research work.

GRADUATE CERTIFICATE PROGRAMS

The Department of Work Environment now offers four graduate certificates in Environmental Risk Assessment, Identification and Control of Ergonomic Hazards, Radiological Health Physics and General Work Environment Protection and Job Stress and Health Job Redesign. Certificates, requiring a minimum of twelve graduate credits (4 courses) offer advanced courses in these subject areas.

Certificate in Environmental Risk Assessment

Purpose: This program provides a solid introduction to the methods of risk assessment, with strong emphasis on their limitations and the policy context in which they currently are applied. A student who successfully completes the program of study will be able to critically read and evaluate risk assessments performed by others, as well as carry out original quantitative analyses of new problems. A student who becomes deeply interested in the field will be more than one quarter of the way to earning a master's degree in Work Environment with a concentration in epidemiology.

Who Should Apply: Professionals working in environmental management, environmental health, occupational health, occupational safety, and food and drug safety, will find the program relevant to their work. Government regulatory agencies, consulting firms in the health and environmental field, and corporate risk management teams often produce or use risk assessments. Because of the advanced level of the program, students must bring to it a background of graduate level training in one of two areas: epidemiology and biostatistics or exposure assessment in either the occupational or environmental health fields. Applicants must have a bachelor's degree in a related field, and strong quantitative skills, including undergraduate mathematics through at least one semester of calculus.

Program:

1. Required courses for students with industrial hygiene or exposure assessment background: Introductory Biostatistics and Epidemiology, Intermediate Biostatistics and Epidemiology, Risk Assessment, and Quantitative Basis of Environmental Health Regulation.

2. Required courses for students with epidemiology or biostatistics background: Introduction to Industrial Hygiene and Ergonomics, Quanitative Basis of Environmental Health Regulation, Risk Assessment, and Exposure Assessment.

Certificate in Identification and Control of Ergonomic Hazards

Purpose: The certificate will give an individual the ability to recognize and control ergonomic hazards in the workplace. Injuries and illnesses such as low-back injuries, upper extremity cumulative trauma disorders, and workplace stress that are due to ergonomic hazards are prevalent and costly to industry. Ergonomic hazards are present in all industry sectors, including manufacturing, construction, shipping, and service industries. Many companies, especially those smaller in size, will not have an ergonomist on staff, though many will have someone with related responsibilities, such as an industrial hygienist, safety specialist, or occupational nurse. Upon earning the certificate, a student will be more than one-quarter of the way to earning a master's degree in Work Environment with a concentration in ergonomics.

Who Should Apply: The program is designed for health and safety professionals (for example, a safety manager, safety engineer, industrial hygienist, occupational health nurse, occupational physician, or physical therapist) already working in industry. Most students will be working full-time in one of these positions. Most students will have bachelor's degrees in engineering or biological sciences; some of them will have master's degrees in these fields.

Program:

Required Courses: Introduction to Industrial Hygiene and Ergonomics, Occupational Biomechanics, and Methods of Work Analysis.

Elective Courses: Physical Agents, Design for Injury Prevention, and Human Factors.

Certificate in Radiological Health Physics and General Work Environment Protection

Purpose: This program provides advanced instruction about radiation and general work environment protections for professionals with health and safety responsibilities.

Who Should Apply: Graduate students majoring in either radiological sciences and protection or work environment are likely candidates for this program. Students should have a bachelor's degree in a quantitative field and college courses in physics, chemistry, calculus and statistics. Many professionals in small to medium-sized industries have responsibility for health and safety with little or no formal instruction. Industries that use radioactive material or radiation and have no formal radiation protection or radiological health physics department often assign these responsibilities to employees who have more general work environment or safety responsibilities. It is also not uncommon for large industries that are licensed to possess and use radioactive material to assign general work environment responsibilities to the radiological health physics staff. Professionals with basic training in both general work environment and radiological health physics are particularly well-suited to work in small and medium-sized industries and to obtain top management positions responsible for all health and safety-related departments in large industries, government laboratories, and universities. The need for professionals in this field is projected to increase dramatically and continue for decades.

Program: The program is a collaborative endeavor between the university's Physics and Radiological Sciences Program and the Work Environment Program. No other college or university in New England offers this type of program. This certificate requires 14 credits of course work earned by taking four courses.

Required courses: Radiation Safety and Control I, Radiation Safety and Control II and Introduction of Industrial Hygiene and Ergonomics.

Elective Courses: (select one) Physical Agents, Engineering Controls and Protective Equipment, Design for Injury Prevention or Field Evaluations.

Certificate in Job Stress and Healthy Job Redesign

Purpose: The professional will learn to identify social and psychological job-related stressors and to devise strategies to reduce the work environment causes of these hazards thus reducing the escalating magnitude of these problems and improving organizational effectiveness. The program is, in part, a response to rapidly rising levels of Workmen's Compensation cases with job stress components.

Who Should Apply: Personnel managers, occupational rehabilitation professionals, union representatives, occupational health professionals and other service and manufacturing professionals who need state-of-the-art understanding of the social and psychological causes of psychosocial stress hazards at work and solutions focused on reduced health risks and improved job productivity. Other candidates are graduate students at nearby universities who want to take advantage of this unique program at Lowell.

Program: This certificate program is offered in conjunction with the Psychology Department at Lowell. Four, three-credit courses, offered in the evenings or late afternoons, are required.

Required courses: Human Factors, Work and Family Roles in Adulthood or Introduction to Work Environment, and Healthy Work Organization Design.

Elective Courses (select one): Helping Skills II, Workplace Diversity, Labor and Technology or Methods in Work Analysis.

COLLEGE OF Health Professions

Dean

Janice M. Stecchi
Professor and Dean: B.S., Boston College; M.Ed., Salem State College; M.S., Boston University; Ed.D., Boston University.

The graduate programs of the College of Health Professions prepare health care providers with specialized knowledge and skills for the roles of practitioner, leader and researcher. The majors include: Master of Science degree in Clinical Laboratory Sciences, Health Services Administration, Nursing and Physical Therapy. The Doctor of Philosophy is offered in Nursing. Graduate certificates are available in some academic majors.

DEPARTMENT OF Physical Therapy

Department Chair and Graduate Coordinator

Joseph A. Dorsey
Professor, B.S., Springfield College; M.Ed., Northeastern University; C.A.G.S., New York University; Ed.D., Boston University.

Faculty

Sue Bergmeier
Assistant Professor, B.S., Russell Sage; M.A. Columbia University; Sc.D., Boston University.

Claire Chamberlain
Associate Professor; B.S., M.Ed., Tufts University; C.A.G.S., Northeastern University.

Barbara Cocanour
Professor; A.B., The Defiance College; M.S., Ph.D, University of Maine.

Sean Collins
Instructor, B.S., M.S., University of Massachusetts Lowell.

Brian W.M. Don
Assistant Professor, B.S., Brighton University U.K.; M.S., Ed.D., Boston University.

Gerard J. Dybel
Assistant Professor; B.S., Indiana University; M.P.T., Baylor University; M.Ed., University of Toledo.

Lisa Falvo
B.S., University of Massachusetts Lowell; M.S., Springfield College.

Linda Kahn-D'Angelo
Professor; B.A., Merrimack College; M.S. in P.T., Texas Women's University; Sc.D., Boston University.

Susan O'Sullivan
Professor; B.S., M.S., Ed.D., Boston University.

Connie P. Seymour
Associate Professor; B.S., M.S., California State Polytechnic; M.P.T., Baylor University; Ph.D., University of Toledo.

Joyce White
Associate Professor; B.S. University of Connecticut; M.S., D. Sc., Boston University.

PHILOSOPHY

The faculty of the Department of Physical Therapy believes that individuals have intrinsic worth and a right to optimal health which enables them to interact effectively in a changing environment. To this end, members of society are responsible for taking an active and cooperative role in personal health and maintenance. When physical, biological, psychological or social changes occur they may cause deficits in effective functioning. Physical therapy is integral to the prevention of disability caused by these changes as well as to the maintenance or rehabilitation of individuals to their optimal level of functioning.

The physical therapist is prepared in an academic program which synthesizes undergraduate background with graduate study that integrates professional physical therapy knowledge, theory and psychomotor skills. The graduate of the Department of Physical Therapy is an ethical and competent professional who uses the problem solving approach and research process for clinical practice, teaching, management, consulting and advocacy. Commitment to life long learning is the basis for continued personal and professional growth.

The faculty believe that students are active participants in the educational process. As potential professionals, the relationship between students and faculty is one in which there is mutual respect, understanding and interchange of ideas. Faculty, as experienced professionals are resource persons, counselors, facilitators, motivators and role models for the potential professional. Students are self-directed, committed and motivated.

Graduates are prepared to assume a leadership role in health care by practicing autonomously and cooperatively in a variety of settings in the medical and industrial economic sector such as: hospitals; rehabilitation centers; schools; extended care facilities; work environments; sports medicine; community health and private practices.

Program of Study

The Department of Physical Therapy at the University of Massachusetts Lowell offers an entry level graduate curriculum of three components: cardiopulmonary, neurological and musculoskeletal physical therapy concepts, techniques, and skills. The course of study is designed to synthesize graduate study, undergraduate knowledge, and experiential learning to prepare graduates to be general practitioners of physical therapy with the capability to fulfill their roles as researchers, educators and consultants.

The graduate degree requires a two and one-half year program of study, during which students participate in a variety of clinical experiences.

Program Objectives

The graduate of the Master of Science degree program in Physical Therapy at the University of Massachusetts Lowell will be prepared to:

1. Maintain respect for human dignity in interaction with others.
2. Promote the prevention of disability, the rehabilitation to and the maintenance of optimal function through the practice of physical therapy.
3. Synthesize the knowledge of the pure and applied sciences, sociology, psychology and human values with the knowledge, theory and psychomotor skills of physical therapy.
4. Evaluate the physical therapy needs of individuals of all ages using the problem-solving approach.
5. Implement a physical therapy plan of care based on identified needs.
6. Communicate effectively with colleagues, clients and families.
7. Utilize psychomotor and affective skills in the treatment of clients.
8. Practice physical therapy in a safe, effective, ethical and legal manner in a variety of health care settings.
9. Coordinate the results of pertinent research reported in the literature in the delivery of physical therapy services.
10. Advance the theory and practice of physical therapy through research.
11. Integrate teaching and learning principles in all facets of physical therapy practice.
12. Promote and facilitate necessary change within the health care delivery systems to assure quality health care.
13. Facilitate the practice of health promotion and disease prevention.
14. Practice autonomously in a leadership role in a variety of clinical settings as a facilitator, counselor and motivator.
15. Utilize principles of formal organization, organizational behavior and management in the delivery of physical therapy services.
16. Collaborate with health practitioners, consumers, and governmental agencies to provide cost effective health care of high quality.
17. Demonstrate a commitment to personal and professional development.
18. Adhere to the code of ethics promulgated by the American Physical Therapy Association.

Admission Requirements

1. Baccalaureate degree from an accredited college or university.
2. Undergraduate grade point average minimum of 3.0.
3. Undergraduate science grade point average minimum of 3.0.
4. Graduate Record Examination minimum of 1300 (combined scores).
5. Personal experience in a physical therapy setting as a volunteer or employee. Minimum 35 hours.
6. Three letters of recommendation. One must be from a Physical Therapist.
7. Highly qualified candidates will be invited for a personal interview.
8. A completed departmental Prerequisite Course Checklist.

Students may be asked to provide documentation of the course content being proposed to meet admissions criteria.

Faculty support the APTA position to actively recruit and retain students who are disadvantaged by reason of ethnic, cultural or economic background and others who are likely to serve critical needs areas.

Additional Requirements

1. Students are responsible for carrying malpractice insurance.
2. Proof of immunization acquired within six months prior to admission for measles, mumps, rubella, tetanus, polio, diptheria and tuberculosis is required.
3. Applicants must provide a report of a physical examination by a physician conducted within six months prior to admission indicating present general health status.
4. The clinical education component of the curriculum is directed by the academic coordinator of clinical education in collaboration with physical therapy faculty. It includes three full-time clinical education experiences of six, eight and eight weeks respectively. These full-time experiences occur in the summer following the first year of study and in the summer and fall following the second year. They are provided in collaboration with a variety of health care facilities throughout the United States.

An integrated experience of one week

duration is scheduled in each academic semester beginning in the spring of the first year. These short term experiences will occur in a variety of clinical facilities within New England.

Physical therapy students are responsible for all costs related to clinical education including transportation, housing, meals and tuition/fees. Students should expect and plan for out-of-state clinical placements. Students are expected to dress in a professional manner while on integrated and full-time clinical assignments.

General prerequisites include:

English composition 3 credits
literature 3 credits

Social and Behavioral Science

9 credits of psychology including:
- 3 credits developmental
- 3 credits interpersonal relation ships
- 3 additional credits
- 3 credits sociology

Biological Science
- 8 credits anatomy & physiology with labs

Chemistry
- 8 credits general with lab

Physics
- 8 credits with labs

Statistics
- 3 credits

Computer Science
- 3 credits or demonstrated knowledge

Professional Prerequisites

Pharmacology
- 3 credits

Kinesiology
- 4 credits with lab Exercise

Physiology
- 4 credits with lab

Application Must Be Received by January 15th.

Students may be asked to provide documentation of the content of courses taken to meet admission criteria.

Course of Study

Year One
Fall

34.601	Clinical Anatomy	3
34.603	Clinical Anatomy Lab	1
34.605	Basic PT Procedures Lecture	3
34.607	Basic PT Procedures Lab	1
34.609	Medical/Surgical Conditions	6
34.613	Principles of Clinical Teaching	3
	TOTAL:	17

Spring

34.602	Neuroscience: Anatomy	3
34.604	Neuroscience: Physiology/Neurology	3
34.606	Neuroscience Lab	1
34.608	Musculoskeletal PT I Lecture	3
34.610	Musculoskeletal PT I Lab	1
34.612	Cardiopulmonary PT Lecture	3
34.614	Cardiopulmonary PT Lab	1
34.616	Research Methods	3
	TOTAL:	18

Integrated Clinical Experience (1 week)

Summer

34.615	Clinical Education Experience I (6 weeks, 2 credits)	

Year Two
Fall

34.617	Neurological PT I Lecture	3
34.619	Neurological PT I Lab	1
34.621	Musculoskeletal PT II Lecture	3
34.623	Musculoskeletal PT II Lab	1
34.625	Electrophysiology Procedures	3
34.627	Electrophysiology Procedures Lab	1
34.629	Research Seminar	2
34.631	Pediatric PT Lecture	3
34.633	Pediatric PT Lab	1
	TOTAL:	18

Integrated Clinical Experience (1 week)

Spring

34.618	Management & Ethics in PT	3
34.620	Neurological PT II Lecture	3
34.622	Neurological PT II Lab	1
34.624	Directed Research	1
34.626	Geriatric PT	3
34.628	Musculoskeletal PT III Lecture	3
34.630	Musculoskeletal PT III Lab	1
34.632	Special Topics in PT	1
	TOTAL:	18

Integrated Clinical Experience (1 week)

Summer/Fall

34.634	Clinical Education Experiences II	
34.635	Clinical Education Experiences III	

(16 weeks, 4 credits)

77 semester hours to complete program.

COURSE DESCRIPTIONS

34.601 Advanced Anatomy (3-0)3 Advanced Anatomy is a study of the structures of the human body, utilizing lectures, demonstrations and audiovisual materials.

34.602 Neuroscience: Anatomy (3-0)3 This course presents the structural features of the central nervous system as they relate to problems encountered in clinical neurology.

34.603 Clinical Anatomy Laboratory (0-3)1 Advanced anatomy laboratory is a visualization of the structures of the human body utilizing laboratory dissection of prosected parts and human cadavers. The laboratory also incorporates the recognition of underlying structures using surface anatomy and palpation of bony and soft tissues.

34.604 Neuroscience: Physiology and Neurology (3-0)3 Neuroscience presents the principles of neurophysiology, neurology, and motor control as related to the practice of physical therapy. Topics in neurophysiology include: conduction and transmission of the nerve impulse, neuromuscular synaptic transmission and skeletal muscle contraction, muscle tone and spinal reflexes, the neurophysiology of sensation and movement, and the transmission of pain. Neurological conditions will be integrated with these various neurophysiological topics through the use of case studies and will include: peripheral nerve injuries, neuromuscular conditions, and diseases/conditions of the central nervous system. An introduction to the major theories of motor control and their application to physical therapy evaluation and treatment will be discussed through problem solving and case studies.

34.605 Basic Physical Therapy Procedures Lecture (3-0)3 This course introduces students to the principles of patient evaluation and treatment utilizing the problem solving framework of the problem oriented medical record system. The purpose and appropriate use of evaluation procedures, and the rationale for safe and effective use of treatment procedures are emphasized. Topics include: organization of patient records, patient interviewing, isolation/sterile techniques, monitoring of vital signs, body mechanics, patient positioning, transfers, gait training and activities of daily living with assistive devices, wheelchair prescription and mobility, heat and cold modalities, and hydrotherapy.

34.606 Neuroscience Laboratory (0-3)1

Neuroscience laboratory includes study of the anatomy and function of the human brain, spinal cord, peripheral and autonomic nervous systems through prosection, audiovisual resources and experimental procedures. The gross anatomy of the human brain and spinal cord will be visualized using prosections of human specimens, models, and slides. Experimental procedures include electromyographic recording of muscle action potentials, evaluation of reflex function in normals, assessment of sensory and cerebellar mechanisms, and testing cranial nerve function. In order to synthesize this course content each student will present a neuropathology case study.

34.607 Basic Physical Therapy Procedures Laboratory (0-3)1 This laboratory course develops psychomotor skills to allow clinical application of didactive knowledge gained in Basic Physical Therapy Procedures Lecture. The safe and effective performance of various evaluation and treatment techniques are emphasized along with appropriate and effective communication skills. Topics include: patient interviewing; isolation/sterile techniques; monitoring vital signs, patient positioning and bed mobility; transfers, gait training and activities of daily living with assistive devices; wheelchair mobility; massage techniques, cold and heat modalities, hydrotherapy.

34.608 Musculoskeletal Physical Therapy I Lecture (3-0)3 This course is the first of a three-course series which explores physical therapy management of musculoskeletal dysfunction. In this first course, general models for physical therapy intervention will be presented. The evaluation, treatment and prevention of pathological conditions affecting the musculoskeletal system of the lower extremity will be emphasized. Normal function will be included as a basis for recognizing and therapeutically resolving dysfunction of skeletal and joint structures, muscles and soft tissues. A problem-solving approach will be utilized in providing patient care.

34.609 Medical Surgical Conditions (3-0)3 This course is an introduction to the study of disease and provides an overview of common medical surgical conditions encountered by the physical therapist. Mechanisms of normal cell growth, cell response to injury and inflammation and cell death are reviewed. This is followed by an introduction to neoplastic disease and oncology. Emphasis is placed on inherited and acquired immunodeficiency disorders, infectious diseases, medical genetics, endocrine and metabolic disorders, gastrointestinal, hepatic and pancreatic disorders, nephrology and disorders of the integumentary system. Special emphasis is placed on the physical therapist's role in the clinical management of clients with selected diseases and conditions. The second half of this course focuses on diseases and conditions of the musculoskeletal system with an emphasis on the medical/surgical management of various orthopedic conditions.

34.610 Musculoskeletal Physical Therapy I Lab (0-3)1 This laboratory course encourages the development of the psychomotor skills to allow clinical application of didactive knowledge gained in Musculoskeletal Physical Therapy I Lecture.

34.612 Cardiopulmonary Physical Therapy (3-0)3 Cardiopulmonary Physical Therapy provides instruction in a variety of pathological cardiopulmonary conditions encountered by physical therapists. The course emphasizes assessment and treatment procedures employed by physical therapists in dealing with these conditions. Students will be expected to integrate and synthesize information from related courses in a variety of cardiopulmonary problem solving experiences

34.611 Principles of Clinical Teaching (3-0)3 This course focuses on the principles of teaching and learning theory and the dynamics of teacher effectiveness as it applies to physical therapy and the clinical setting. Discussions will center on the identified qualities of organization, clarity, enthusiasm, stimulation, instructor knowledge, the ability to instruct in a group and the ability to supervise in a treatment setting. Emphasis is placed on creating a climate that encourages learning. A teaching experience will be planned, implemented and evaluated by each student.

34.614 Cardio-Pulmonary Physical Therapy Laboratory (0-3)1 This course is to be taken concurrently with the Cardio-Pulmonary Lecture. Students will be given the opportunity to practice those procedures discussed in Lecture and must demonstrate proficiency in each procedure to successfully complete the course.

34.615 Clinical Education Experience I (0-8)2 A six week full time clinical experience designed to integrate basic physical therapy evaluative and treatment procedures with an emphasis on the musculoskeletal and cardiopulmonary systems. Students are directly supervised by qualified physical therapists in general acute facilities and outpatient settings.

34.616 Research Methods (3-0)3 This course presents the role of research in the development and critical analysis of physical therapy clinical practice. Students are guided through the scientific research process and the following stages are discussed: problem and hypothesis identification, review of the literature, methods of evaluating the hypothesis, data collection, data analysis, interpretation and presentation of the results. Students will work in small groups to develop the components of a research proposal and orally present this proposal to other members of their class.

34.617 Neurological Physical Therapy I (3-0)3 This course is the first of two courses dealing with the therapeutic management of adult patients with neurological dysfunction. A variety of assessment and treatment procedures available to the physical therapist will be explored. Integration of treatment approaches will be emphasized. Theoretical models based on normal sensorimotor development, neurophysiology and motor control, and motor learning will be discussed as a base for clinical decision making. Concurrent laboratory sessions will emphasize the development of specific psychomotor skills necessary for the successful assessment and treatment of adult patients.

34.618 Management and Ethics in Physical Therapy (3-0)3 This course provides an overview of the operation of physical therapy services within the structure of the United States health care system. The course will evolve from a macro approach concerning the issues and trends in the delivery of health care and their implications for the management of physical therapy services, to a micro view exploring the function and interaction of the physical therapist within the health care organization.

34.619 Neurological Physical Therapy I Lab (0-3)1 Through classroom laboratory experiences, the student will be given the opportunity to gain beginning skill in the practical application of assessment and treatment procedures for patients with neurological dysfunction.

34.620 Neurological Physical Therapy II Lecture (3-0)3 This course is the second of two courses dealing with the therapeutic management of adult patients with neurological dysfunction. A variety of assessment and treatment techniques available to the physical therapist will be explored. Integration of treatment approaches will be emphasized. Theoretical models based on normal sensorimotor development, neurophysiology and motor control, and motor learning will be used as a base for clinical decision making. Concurrent laboratory sessions will emphasize the development of specific psychomotor skills necessary for the successful assessment and treatment of adult patients.

34.621 Musculoskeletal Physical Therapy II Lecture (3-0)3 This course is the second of a three-course series which focuses on physical therapy management and summarizes medical and surgical management of musculoskeletal dysfunction. The evaluation, treatment and prevention of pathological conditions affecting the upper extremity and distal lower extremity will be emphasized. Normal function will be included as a basis for recognizing and therapeutically resolving dysfunction of skeletal and joint structures, muscular and soft tissue. A problem-solving approach will be utilized in providing patient care.

34.622 Neurological Physical Therapy II Lab (0-3)1 Through classroom laboratory experiences, the student will be given the opportunity to gain continued skill in the practical application of assessment and treatment procedures for patients with neurological dysfunction.

34.623 Musculoskeletal Physical Therapy II

Lab (0-3)1 This laboratory course develops the psychomotor skills to allow clinical application of didactic knowledge gained in Musculoskeletal Physical Therapy II Lecture.

34.624 Directed Research (3-0)3 This course is the application of research design and methodology culminating in the completion of a project or thesis under the guidance and supervision of the faculty.
Comprehensive case studies will also be presented and discussed.

34.625 Electrophysiological Procedures (3-0)3 This course is a study of advanced physical therapy procedures which utilize electrophysics and electrophysiology in evaluating and treating patients. The course will emphasize theories and techniques used in electrodiagnosis, electromyography, functional electrical stimulation, iontophoresis, transcutaneous electrical stimulation, biofeedback, laser and therapeutic electrical currents.

34.626 Geriatric Physical Therapy (3-0)3 The focus of this course is the changes in the cardio-pulmonary, musculoskeletal and neurological systems of the elderly that will affect physical therapy management.
Emphasis is placed on special needs of the elderly with respect to exercise, psychosocial, nutritional needs and pharmacology and compliance issues.

34.627 Electrophysiology Procedures Laboratory (0-3)1 This course is a practical application of theories and principles presented in 34.625, Electrophysiology Procedures.

34.628 Musculoskeletal Physical Therapy III Lecture (3-0)3 This course is the last in a three-course series which focuses on physical therapy management and summarizes medical and surgical management of musculoskeletal dysfunction. The evaluation, treatment and prevention of pathological conditions affecting the spine, posture and gait will be emphasized. Orthotic and prosthetic use will be included. Normal function will be included as a basis for recognizing and therapeutically resolving dysfunction of skeletal and joint structures, muscular and soft tissue.

34.629 Research Seminar (0-1)1 During this course students will develop a master's project with the guidance of a faculty project advisor. This course will serve as a forum for presenting, discussing and critiqueing the stages of the research development.

64.630 Musculoskeletal Physical Therapy III Lab (0-3)1 This laboratory course develops the psychomotor skills to allow clinical application of didactic knowledge gained in Musculoskeletal Physical Therapy III Lecture.

34.631 Pediatric Physical Therapy (3-0)3 This course focuses on evaluation and treatment of pediatric problems of the CNS and neuromusculoskeletal systems. The development of a theoretical model for evaluation and treatment will be based upon principles of sensorimotor development, neurophysiology, motor control, and motor learning. The course will begin with normal sensorimotor development, evaluation and facilitation of sensorimotor development. The next section will deal with evaluation of problems in sensorimotor development, treatment techniques and strategies. The final section will emphasize problem solving and integration of previously presented material using case studies.

34.632 Special Topics in Physical Therapy (3-0)3 This course introduces the second year physical therapy student to various topics related to specialized physical therapy management of patients. Topics include, but are not restricted to, treating the HIV positive patient, upper and lower extremity prosthetics, orthotics and splint fabrication, burn care, arthritis, the insensitive foot, aquatic therapy, ADA, ergonomic assessment and case study presentations.

34.633 Pediatric Physical Therapy: Laboratory/Clinic (0-3)1 Through classroom and clinical laboratory experiences, the student will be given the opportunity to gain beginning skill in the physical therapy treatment of pediatric clients.

34.634 Clinical Education Experience II (0-8)2 An eight week full time experience which promotes the development of an autonomous professional through the synthesis and utilization of advanced academic theory in evaluation and treatment. Students are expected to use sound scientific rationale and a problem solving approach in all aspects of patient care. Students are allowed to explore areas of interest in a variety of settings.

34.635 Clinical Education Experience III (0-8)2 Final full time eight week clinical experience designed to promote socialization into the profession of physical therapy. Students are expected to function as independently as possible using the problem solving process as a basis for all clinical decision making. Communication, coordination and consultation with other members of the health care team and responsibility for total client management is emphasized.

MASTER OF SCIENCE IN PHYSICAL THERAPY ADVANCED PRACTICE OPTION

The Master of Science in Physical Therapy Advanced Practice Option prepares physical therapists for leadership roles in clinical practice, administration, research, and/or teaching in physical therapy programs.

Curriculum

The curriculum includes 30 credits with a core curriculum of 12 credits. The core will provide the practitioner the opportunity to develop indepth knowledge and skills in concepts of physical therapy assessment and treatment, clinical decision making, policy and education in the health-care field as well as Quantitive Methods. There are 6 credits of required research courses which will culminate in a masters project or thesis. The elective 12 credits allow the student to choose a concentration of courses from the following areas:

A. Advanced Professional Practice
B. Health Services Administration
C. Work Environment
D. Education
E. Area Chosen by Student an preapproved by advisor and chairperson of the department offering the courses

The courses will be offered late afternoons and evenings to facilitate clinicians doing part time study.

Program of Study

CORE COURSES		12 Credits
34.642	Therapeutic Concepts in Advanced Clinical Practice	3
34.643	Differential Diagnosis & Decision Making in P.T.	3
32.625	Health Policy	3
32.606	Quantitative Methods (in HSA program)	3
		TOTAL:12
REQUIRED RESEARCH COURSES		6 Credits
34.616	Research Methods Section 202	3
34.629	Research Seminar	2
34.624	Directed Research	1
		TOTAL:6
CONCENTRATION AREA		12 Credits
A.	Advanced Clinical Practice	
34.645	Advanced Concepts in Musculoskeletal Physical Therapy: The Upper Extremity	3
34.652	Advanced Concepts in Musculoskeletal Physical Therapy:Lower Extremity	3
34.646	Advanced Concepts in Musculoskeletal: Spine I	3
34.647	Advanced Concepts in Musculoskeletal Spine II	3
34.648	Advanced Concepts in Cardiopulmonary Physical Therapy	3
34.649	Advanced Neurological Physical Therapy	3
34.650	Advanced Concepts in Geriatric Physical Therapy	3

34.651	Special Topics in Pediatric Physical Therapy	3
34.653	Transcultural Perspectives in Clinical Practice Education and Health Policy*	3
34.654/5	Independent Study of Special Topics*	3
B.	Health Services Administration	
32.602	Organizational Behavior in Health Care Services	3
32.604	Principles of Epidemiology	3
32.607	Health Care Information Systems	3
32.627	Marketing and Planning Health Care Services	3
32.614	Health Care Management	3
C.	Work Environment	
19.521	Introduction to Industrial Hygiene and Ergonomics	3
19.531	Occupational Biomechanics	3
19.638	Methods of Work Analysis	3
19.540	Design for Prevention of Injury	3
19.542	Human Factors	3
D.	Education	
04.636	Theory and Research in Curriculum	3
04.639	Planning Process: Curriculum	3
04.650	Practicum in Curriculum and Instruction	3
04.642	Politics of Curriculum Change	3
E.	Concentration	

Identified by student and preapproved-by advisor and chairperson of department offering courses.

Admission Requirements

A BS or MS degree in physical therapy from an accredited program
Minimum cumulative grade point average of 3.0 in entry-level P.T. degree
Three professional letters of reference pertaining to academic ability and professional competency
Pre-admission interview
Graduate Record Scores (Baccalaureate students only)
Professional licensure in physical therapy
Two years or an equivalent of two years full-time experience as a physical therapist

*Applications are accepted at any time throughout the year.

*Can be used towards any concentration area

For information regarding Program of Study, please contact:

Dr. Joseph Dorsey or
Dr. Linda Kahn-D'Angelo
Department of Physical Therapy
College of Health Professions
University of Massachusetts Lowell
Lowell MA 01854
(978) 934-4517
(978) 934-4411
FAX (978) 934-3006

For a catalog and application materials, please contact:

The Graduate School
University of Massachusetts Lowell
One University Avenue
Lowell MA 01854
(978) 934-2380
(800) 656-GRAD
FAX (978) 934-3022

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Please see other Department Course Descriptions for Work Study, Education and or Health Services Administration.

Core Courses

34.642 Therapeutic Concepts in Advanced Clinical Practice This course will present the physiological processes of physical therapy practice at an advanced level. Topics will include disease, healing, rehabilitation and disease prevention.

34.643 Differential Diagnosis and Clinical Decision Making in Physical Therapy This course will emphasize the development of evaluation strategies, documentation skills, and patient management principles. Discussions and exercises will focus on developing patient diagnoses, functional problem lists, long and short term goals, and effective treatment programs. Critical thinking/problem solving strategies will be incorporated into all aspects of patient management. Emphasis will be on creating a climate that encourages learning.

34.606 Quantitative Methods The course is designed to provide students with an understanding of the application of biostatistical methods to problems in health services administration. Topics include chi-square, t-tests, correlation, analysis of variance, multiple and logistic regression, plus introduction to survival analysis and power analysis. Main areas of emphasis are 1) determination of appropriate procedures for analysis of a given problem in health services, 2) utilization of computer software to carry out the data analysis, 3) interpretation of statistical results of the analysis, and 4) interpretation of results in substantive terms understandable to other health professionals and to the public. Prerequisite, an elementary statistics course.

32.625 Health Policy This course will examine and critically analyze the United States health care system, emphasizing the major trends and issues which have lead to the current sense of "crisis". In addition to providing a historical perspective, this course will establish a context for analyzing the current, varied approaches to health care reform. While the course will focus on U.S. health care system financing issues, there will be a comparative review of the systems of other nations, and several sessions will concentrate on the needs of special populations.

Research Courses

34.616 Research Methods This course presents the role of research in the development and critical analysis of physical therapy clinical practice. Students are guided through the scientific research process and the following stages are discussed: problem and hypothesis identification, review of the literature, methods of evaluating the hypothesis, data collection, data analysis, interpretation and presentation of the results. Students will work in small groups to develop the components of a research proposal and orally present this proposal to other members of their class.

34.629 Research Seminar During this course students will develop a master's project/thesis proposal with the guidance of a faculty project advisor, and instructor of the Research Seminar. This course will serve as a forum for presenting, discussing and critiqueing the students' research proposals.

34.624 Directed Research This course is the application of research design and methodology culminating in the completion of a project or thesis under the guidance and supervision of the faculty. Comprehensive case studies will also be presented and discussed. Concentration Area A - Advanced Physical Therapy Practice

34.650 Advanced Concepts in Geriatric Physical Therapy This course will provide the learner with the most recent information on the rehabilitation of the geriatric patient. A seminar format will include discussions on the special needs of the elderly with respect to physical therapy management. Changes in the body systems associated with normal aging, and pathological changes associated with common diseases and conditions of the elderly will be discussed. Assessment tools and intervention strategies commonly used with the elderly will be discussed and analyzed. Outcome measures and documenation guidelines will also be presented. Extensive reading and handouts will provide the foundation for analysis and discussion.

34.645 Advanced Musculoskeletal Physical Therapy: Upper Extremity This course focuses on advanced physical therapy evaluation and treatment methods

appropriate for musculoskeletal disorders affecting the upper extremity: shoulder, elbow, wrist and hand. Lectures, readings, group discussions and supervised laboratories will be utilized to present relevant anatomy, kinesiology, pathology, assessment techniques and treatment techniques such as joint and soft tissue mobilization and exercise programs. Theoretical background as well as clinical skills will be emphasized.

34.652 Advanced Musculoskeletal Physical Therapy: Lower Extremity This course focuses on advanced physical therapy evaluation and treatment methods appropriate for musculoskeletal disorders affecting the lower extremity: hip, knee and ankle/foot. Lectures, readings, group discussions and supervised laboratories will be utilized to present relevant anatomy, kinesiology, pathology, assessment techniques and treatment techniques such as joint and soft tissue mobilization and exercise programs. Theoretical background as well as clinical skills will be emphasized.

34.646 Advanced MS Evaluation and Rx: Lumbar Spine and Pelvis This course provides the practicing physical therapist a comprehensive clinical model for management of dysfunction fo the lumbar spine and pelvis. A comprehensive foundation of functional anatomy will be developed. The development of evaluation strategies, documentation skills, organized clinical decision making and effective patient management techniques will be emphasized. Labs will provide the student an opportunity to apply didactic knowledge in developing a functional approach to patient management of the lumbar spine and pelvis.

34.647 Advanced MS Evaluation and Rx: Cervical, Thoracic Spine and TMJ This course provides the practicing physical therapist a comprehensive clinical model for management of dysfunction of the cervical, thoracic spine and the temporomandibular joint (TMJ). A comprehensive foundation of functional anatomy will be developed. The development of evaluation strategies, documentation skills, organized clinical decision making and effective patient management techniques will be emphasized. Labs will provide the student an opportunity to apply didactic knowledge in developing a functional approach to patient management of the cervical, thoracic spine and the TMJ.

34.648 Advanced Cardiopulmonary Physical Therapy The emphasis of this course is on the pathological and treatment considerations for a variety of cardiac and pulmonary dysfunctions encountered in physical therapy. An analysis of a variety of evaluation tools is presented i.e. ECG, echocardiograms, arteriograms, ventilation control, thalium scanning and enzyme monitoring. Students will be acquainted with a variety of treatment procedures along with the mechanism of application and the physiological basis for their use.

34.649 Advanced Concepts in Neurological Physical Therapy This course will provide the learner with the most recent information on the neurological rehabilitation of patients. A seminar format will include discussions on current evaluation tools and assessment procedures. Treatment protocols or approaches will be critically analyzed for relevance and appropriateness in light of current theories of motor control and motor learning. Outcome measures and documentation guidelines will also be discussed. Extensive readings and handouts will provide the foundation for analysis and discussion.

34.651 Special Topics in Pediatric Physical Therapy This course will be a research driven seminar on special topics in pediatric physical therapy including physical therapy in the special care nursery, Early Intervention, and the Education Environment.

34.653 Transcultural Perspectives in Clinical Practice Education & Health Policy This course will explore the impact of a multicultural society on the effective practice of physical therapy. Specific issues relating to practice, education, and health policy will be addressed.

DEPARTMENT OF
Health and Clinical Sciences

Department Chair
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Professor; B.A. University of Iowa; M.A., M.P.H., Ph.D., University of Michigan.

Graduate Coordinator
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MASTER OF SCIENCE DEGREE PROGRAM IN CLINICAL LABORATORY SCIENCES

Philosophy of the Department of Clinical Laboratory Sciences

The Department of Clinical Laboratory Sciences believes that every individual is entitled to quality health care, the delivery of which is in part based on continuous advancement in the clinical laboratory sciences. Dynamic technological developments in the clinical sciences have demanded a need for continuous and advanced training. In response to this demand, the Department of Clinical Laboratory Sciences believes that graduate education is necessary to prepare the laboratory professional in this rapidly changing environment. The clinical laboratory scientist utilizes knowledge from the clinical, biological and physical sciences which may be integrated with education and administrative methodology in problem solving and the investigation of dynamic developments in the clinical laboratory. A graduate of the program is one who applies scientific theory to the application of clinical investigation and diagnosis, generates new knowledge and assumes responsibility for continuous education in order to achieve a leadership position within the profession. A graduate of the Master of Science degree program in Clinical Laboratory Sciences is an ethically responsive professional.

Program Intent

The Master of Science degree program in Clinical Laboratory Sciences provides medical technologists and individuals with medical and/or biological backgrounds with specialized knowledge in the clinical laboratory sciences. Individuals will expand their understanding of the clinical sciences and be able to apply state-of-the-art research techniques to the advancement of diagnostic technology. Knowledge of such skills will permit upward mobility into entry level supervisory positions and dissemination of clinical information in educational settings. The program integrates science components from the College of Arts and Sciences, educational components from the College of Education and management components from the Health Services Administration program in the College of Health Professions.

Program Goals

Each student upon completion of the program is expected to:

1. Integrate knowledge from specialized areas of clinical research, management and education.
2. Demonstrate competencies and advanced skills in areas of clinical specialization, research, management and education.
3. Demonstrate ability to make decisions necessary for management and supervision of a clinical laboratory.
4. Utilize teaching and management competencies to educate and supervise laboratory personnel in respective areas of specialization.
5. Demonstrate knowledge and application of research methodology.
6. Utilize research to improve the state of the art in techniques, management or education of clinical laboratory sciences.
7. Equip and manage a clinical laboratory efficiently and cost effectively.
8. Collaborate with members of other health care specialties.
9. Show evidence of continuous professional growth and leadership.

Admission Requirements

- Baccalaureate degree from an accredited university or college.
- Undergraduate scholastic average of 3.0 or better recommended.
- Clinical certification for concentration in administration and education options.
- Sound preparation in biological or clinical sciences with chemistry background for research concentration.
- Official score report for the Graduate Record Examination Aptitude Test.
- Satisfactory completion of the following prerequisite:
- Clinical Chemistry or equivalent for Clinical Research concentration.
- Three letters of recommendation pertaining to academic ability and professional performance.

Program Requirements

1. Credits

The student must have completed prior to admission, or may complete without credit within the graduate program of study, an introductory course in computers and a course in statistics prior to the third semester.

Degree Requirements

The Master of Science degree program in Clinical Laboratory Sciences requires the successful completion of a minimum of 30 semester hours of graduate level courses. These include 15 credit hours of core courses, 4-8 credit hours of research project or thesis as well as a selection of 9-12 credits from from one of the areas of concentration: Clinical Research, Clinical Education or Clinical Administration.

A project (4 Cr),which will consist of a scholarly investigation or a Thesis (8 Cr) is required for all areas of concentration. There is no formal foreign language requirement.

2. Program of Studies

Core Curriculum

The core curriculum includes the following courses and must be taken by each program student:

30.550	Human Development and Pathophysiology	3
36.555	Clinical Laboratory Management	3
32.604	Epidemiology	3
36.575	Topics in Clinical Laboratory Sciences	3
36.553	Advanced Clinical Chemistry	3
	TOTAL:	15

Concentration Areas

Students matriculating in the Master of Science degree program in Clinical Laboratory Sciences must select a concentration area of either: Clinical Research, Education, or Administration.

A. Clinical Research

Students selecting this concentration are expected to have prior certification or a sound preparation in the biological sciences and chemistry. In addition to the core curriculum, students must take the following prescribed electives:

36.551 Adv. Pathophysiology 3

Students also select Project (4 Cr) or Thesis (8Cr) and 9-12 semester credits from departmental course offerings or from courses approved by the department chair, graduate coordinator or graduate committee.

B. Clinical Education

Students selecting this concentration are expected to have prior certification acceptable to the Department of Clinical Laboratory Sciences. In addition to the core curriculum, students must take the following prescribed electives:

36.551	Advanced Pathophysiology	3

Students also take Project (4 Cr) and the following graduate level education courses:

01.610	Theories of Learning	
02.558	Measurement and Evaluation	3
08.659	Strategies for Instruction in Higher Education	3
	Approved Education Elective	3
	TOTAL:	16

C. Clinical Administration

In order to select this concentration, students must have a clinical certification approved by the chairperson of the Department of Clinical Laboratory Sciences. In addition to the core curriculum, students must take Project (4 cr) and 12 semester credits in the following graduate level Health Administration courses:

32.602	Organizational Behavior in Health Care Services	3
32.614	Health Care Management	3
32.607	Health Care Information Systems	3
32.625	Health Policy	3
	TOTAL:	16

*Note: Other graduate levels course from the Health Services Administration Program may be subsituted for these courses with graduate coordinator approval.

Research Project or Thesis

Each student must either complete a 4 credit project (an original study which integrates concepts, skills and techniques and makes a contribution to the field) or an 8 credit thesis (an in-depth independent investigation of contemporary clinical problems). If selecting a thesis, the student must select a committee and orally defend the work in a Departmental seminar. The thesis is subject to the guidelines and requirements of the Graduate School.

Graduate Certificate in Clinical Pathology

This certificate is appropriate for medical laboratory personnel, nurses, and other medical professionals interested in expanding and updating their knowledge in Laboratory Medicine. The certificate consists of 4 courses offered by the Department of Clinical Laboratory Sciences. Students take 2 required courses (30.550 and 36.551) and two elective courses offered by the Department.

DOCTOR OF PHILOSOPHY DEGREE PROGRAM (Clinical Chemistry/Nutritional Biochemistry Option)

The Department of Clinical Laboratory Sciences offers an option within the Biochemistry Doctorate Program in the Chemistry Department. Students are awarded a Ph.D. in Chemistry. For a full discussion, please see Program description under the Department of Chemistry.

COURSE DESCRIPTIONS

30.550 Human Development and Pathophysiology (3-0)3 Study of the physiological steady state of the human body and disruptions that result over the life span as well as the pathophysiological mechanisms manifested in disease states. Defense, compensating and adaptive responses to the pathophysiological process as they apply to the various systems are examined.

36.551 Advanced Pathophysiology (3-0)3 Prerequisite: Human Development and Pathophysiology or permission of instructor. Disease processes as appropriate and inappropriate variants of normal physiological functions. A detailed examination of certain important and illustrative diseases rather than a survey of diseases in general.

36.553 Advanced Clinical Chemistry (3-0)3 Prerequisite: Clinical Chemistry. This course is designed to give an in-depth understanding in clinical chemistry. Topics include: analytical techniques and the selection of methodologies. A detailed examination of selected clinical disorders will be discussed with a biochemical viewpoint.

36.555 Clinical Laboratory Management (3-0)3 This course will introduce the student to management skills (improving communication, maintaining discipline, handling complaints), personnel relations (labor relations, interviewing, OSHA regulations), laboratory operations and state and federal regulations of the laboratory.

36.559 Pharmacology (3-0)3 Pharmacology is an introduction to the chemistry, biochemistry and physiological actions of various pharmaceuticals. Fundamental concepts will be stressed and will include a discussion of drug receptors, drug receptor interactions, pharmacokinetics, enzyme induction, drug metabolism, drug safety and effectiveness and idiosyncratic reactions.

36.561 Topics in Pharmacology (1-0)1 Prerequisite: Pharmacology.
This course emphasizes the basic principles of drug action as related to modern therapeutics. During this course each student participates in a seminar group concentrating on a specific

aspect of pharmacology; this entails oral presentation of a chosen topic to the group and the writing of a paper.

36.563 Nutritional Biochemistry (3-0)3 This course will integrate biochemistry and physiology to gain a better perspective of how basic nutrients are metabolized during normal life-supporting processes. Subject matter will also include how abnormalities in nutrient metabolism can predispose to acute and chronic disease states.

36.575 Topics in Clinical Laboratory Science (3-0)1 This course provides an opportunity for students to familiarize themselves with recent advances not covered in regular courses. Content varies from year to year so students may, by repeated enrollment, acquire a broad knowledge of contemporary issues. A written and oral presentation will be required as evidence of an ability to organize and evaluate published material.

36.580 Gene Therapy and Clinical Genetics (3-0)3 This course focuses on the clinical laboratory techniques that are used in gene therapy. Modern applications of genetic engineering, data analysis, and genome sequencing technology in the clinical investigation of human disorders are covered.

36.615 Medical Parasitology (3-0)3 Prerequisite: Basic Microbiology. Study of morphology, biology, host-parasite relationship, public health problems and control of protozoa, helminths and arthropods primarily involved with parasitic diseases in man. Laboratory will introduce the most practical and reliable methods of clinical diagnosis.

36.617 Medical Mycology (3-0)3 Prerequisite: Basic Microbiology. A study of the isolation, identification, classification, epidemiology, mycoserology and clinical importance of medically significant fungi. The course will employ diagnostic methods used in the clinical laboratory including the most recent developments.

36.619 Clinical Serology (3-0)3 Prerequisite: Basic Microbiology, Basic Immunology, and Serology. Theory and procedures for identification of antibodies produced as a result of infection by microorganisms, collagen diseases and autoimmune disorders. More modern concepts of immunologic testing as immunodiffusion and fluorescent antibody will be introduced.

36.625 Erythropoeisis (3-0)3 Prerequisite: Hematology and Biochemistry. This course will provide an in-depth review of red blood cell morphology, proliferation and differentiation, as well as introduce the current clinical diagnostic procedures, correlating their results with normal and pathological states.

36.627 The Leukocytes (3-0)3 Prerequisite: Hematology and Biochemistry. An in-depth survey of both normal and pathological granulopoiesis, megakaryopoiesis, and lymphopoiesis. It will also correlate morphological and quantitative clinical diagnostic testing procedures with specific disease states.

36.629 Experimental Hematology in the Clinical Laboratory (1-0)1 Prerequisite: Hematology and Biochemistry. This course will review the current status of experimental hematology and will describe the clinical application of theoretical and technical breakthrough in the facilitation of diagnosis and evaluation of hematological disease states.

36.661 Advanced Clinical Hematology Seminar (1-0)1 Prerequisite: Hematology, Biochemistry or permission of instructor. This course will review selected theoretical and technical topics in the field of clinical hematology. Students will prepare detailed seminars describing current research, clinical case studies, as well as specific problems facing the clinical laboratory scientist.

36.633 Topics in Coagulation (1-0)1 Prerequisite: Hematology, Biochemistry or permission of instructor. A review of all physiological, molecular, and technical aspects of hemostasis. Students will take part in describing the current problems, as well as the ongoing research taking place to further the understanding of both the normal and pathological blood clotting states.

36.657 Clinical Toxicology (3-0)3 Prerequisite: Pharmacology and Biochemistry. Designed to examine the instrumental methods of assay. Toxicologic and pharmocologic action on and by the host organism will be described. Major drugs and toxin types will be reviewed.

36.659 Advanced Instrumentation (3-0)3 A study of current principles of automated analysis as applied to the clinical laboratory. The course will provide practical exposure to several commercially available systems.

36.734 Research Project in Clinical Laboratory Sciences (0-9)4 Prerequisite: Written permission from Graduate Coordinator. Prerequisite: Research Design and Methodology. An independent study or laboratory project which has been approved and is under the direction of the project advisor. Projects are approved by the graduate coordinator in conjunction with the project advisor.

36.744 Thesis (0-9)4 Prerequisite: Research Design and Methodology. Analytical and/or experimental work conducted under the direction of a thesis advisor and in accordance to the Graduate School Guidelines. Students are required to submit a written proposal for approval by a thesis committee and to present an oral defense at a college seminar.

36.406/506 Biochemistry of Lipids (3-0)3 This advanced course in nutritional biochemistry and physiology of lipids will detail the role of lipids in the normal and pathological processes at both the cellular and whole organism level. Topics will range from general discussions of the digestion, absorption and transport of lipids to the role of eirosanoids and lipid soluble anit-oxidents during normal and diseased states.

DEPARTMENT OF HEALTH EDUCATION AND ADMINISTRATION

Department Chair
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Graduate Coordinator
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Beverly J. Volicer
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MASTER OF SCIENCE DEGREE PROGRAM IN HEALTH SERVICES ADMINISTRATION

Philosophy of the Department of Health

The faculty of the Department of Health believes that each individual is a unique rational human being who must have the opportunity to interact effectively within a changing environment. Individuals possess innate rights, one of which is the attainment of the goal of optimal health. Society, through its community and educational institutions, has a responsibility to make available for its citizens the methods and means for achieving the goals for an optimal level of health. To this end the Department of Health is committed to prepare professional practitioners who, from their own health practice discipline, assist the individual, the family, the group and the community to achieve as high a level of health as possible.

Program Intent

The goal of the graduate program in Health Services Administration is to provide health services administrators with the specialized knowledge and skills necessary to administer the delivery of high quality and cost effective health services.

The core curriculum is designed to foster the ability to make administrative decisions based on sound management principles and scientific methods. The computer skills necessary for modern health care and health promotion management are integrated throughout the curriculum.

The program is designed to accommodate individuals already employed in the health care field who wish to further their professional training, and for college graduates preparing to enter the field. Course requirements may be completed on either a full-time or part-time basis.

Admission Requirements

Baccalaureate degree from an accredited institution. An undergraduate scholastic average of 3.0 or better. Three letters of recommendation pertaining to academic ability and professional performance. Personal interviews if requested by departmental faculty. Acceptable score on the Graduate Management Admission Tests (GMAT) or Graduate Record Examination (GRE). Satisfactory completion of prerequisite statistics course.

Program Requirements

1. Credits

Forty-two credit hours of course work will be required of all students enrolled in the program; there are no formal language or comprehensive examination requirements. An internship and thesis or project is required for graduation.

2. Program of Studies

The Master of Science in Health Services Administration consists of 42 credits as follows:

11 Core Courses	33
Internship	6
Project or Thesis	3
	42 credits

These courses must be taken by every student in the program:

32.602 Organizational Behavior in Health Care Services
32.604 Principles of Epidemiology
32.606 Quantitative Methods for Health Services
32.607 Health Care Information Systems
32.611 Health Care Finance
32.612 Operations Analysis for Quality Improvement
32.614 Health Care Management
32.615 Health Care Financial Management
32.625 Health Policy
32.626 Strategic Planning and Management
32.627 Marketing and Planning Health Care Services

All students must also complete the following courses (9 credits):

32.617 Internship and Seminar (6 credits)
32.733 Project

Health Services Administration Program Expected Outcomes

Each student upon completion of the program is expected to:

A. Integrate knowledge from the fields of health services and health systems, management, health, and the behavioral sciences to identify, analyze, and address problems.

B. Apply theory to the administration of health care.

C. Demonstrate specialized administrative competencies including advanced skills in the functions of planning, organizing, controlling and evaluating health care and health promotion.

D. Analyze legal, fiscal, regulatory and environmental factors influencing health care and health promotion.

E. Demonstrate the ability to make effective administrative decisions.

F. Communicate effectively.

G. Demonstrate knowledge of research methodology.

H. Utilize research to improve practice and expand knowledge in health education and administration.

I. Demonstrate basic competency in the financing of health care.

Graduate Certificate in Health Services Administration

A twelve-credit graduate certificate is offered to students who hold a baccalaureate degree in a relevant field from an accredited institution. The certificate consists of 2 required courses and any two courses from the electives listed below:

Required Courses:

32.602 Organizational Behavior (Fall Semester)
32.611 Health Care Finance (Spring Semester)

Electives:

32.607 Health Care Information Systems
32.612 Operations Analysis for Quality Improvement
32.615 Health Care Financial Management
32.626 Strategic Planning and Marketing
32.617 Planning and Marketing for Health Care Services

Students plan course of study in consultation with the Program Coordinator. These courses may be applied to the Master's Degree in Health Services Administration.

COURSE DESCRIPTIONS

32.602 Organizational Behavior in Health Care Organizations (3-0)3
Applies management, behavioral, and social science theory and practice to health care organizations. Management of organizational change is emphasized. Students use course material to analyze management cases in health care.

32.604 Principles of Epidemiology (3-0)3 Basic concepts of epidemiological reasoning in context of current trends in major health problems. Emphasis on interpretation of epidemiological data and application of epidemiological information to management of health care and health promotion.

32.606 Quantitative Methods for Health Services (3-0)3 Application of bivariate and multivariate biostatistical methods to

problems in health care management and health promotion. Emphasis on 1) determinants of appropriate procedures, 2) utilization of computer software for analysis, 3) and interpretation of statistical results. Prerequisite, a statistic course.

32.607 Health Care Information Systems (3-0)3 Introduces computer applications and management issues in health care. Overview of hardware and software products. Management issues attendant to the design and implementation of computerized systems. Alternative strategies considered and presented. Students learn the important components of the systems life cycle.

32.611 Health Care Finance (3-0)3 Presents important macroeconomic aspects of health care economics at the federal, state and local level and describes their effects on health care providers. Instruction in financial accounting, operating budgeting, and cost management and pricing of services.

32.612 Operations Analysis for Quality Improvement (3-0)3 Fundamentals of analysis and control of administrative and clinical operations for the continuous improvement of quality health care. Includes quality management systems and control, design of alternative processes, capacity utilization, quality control and quality auditing.

32.613 Research Methods (3-0)3 Development of knowledge and skills useful for research in health services, ethical and political issues. Topics include study design, measurement, data collection and analysis and interpretation of findings. Applications to program management.

32.614 Health Care Management (3-0)3 Provides framework for addressing management principles and activities in health care organizations.

32.615 Health Care Financial Management (3-0)3 Tools and techniques necessary to manage the financial resources of health care organizations, report financial results, formulate strategic financial plans, and assess the fiscal impacts. Covers financial statements, cost accounting and analysis, financial analysis, capital budgeting and strategic planning methods. Prerequisite, an elementary accounting course or permission of instructor and 32.611.

32.616 Legal Issues in Health Services Administration (3-0)3 Exposes the student to those legal concepts, principles and issues germane to the administration of various health care delivery systems which comprise the American health services model.

32.617 Internship and Seminar (0-9)3 Provides an opportunity to work in health education and administration under a qualified preceptor. Seminars with faculty integrate this experience with academic training. Placement decisions are made by faculty on the basis of student interests, needs, and abilities.

32.625 Health Policy (3-0)3 Provides students with a framework for policy analysis and examines major strands of U.S. health policy. Detailed consideration and discussion of the relationship of national policy to the planning, implementation and funding of health care services.

32.626 Strategic Planning and Management The strategic planning and management of health care organizations is covered. Development and implementation of strategic plans is covered. Alternative theories of organizations and change are explored. The capstone experience for the major. (3-0)3

32.627 Planning and Marketing for Health Care Services (3-0)3 The history, principles and methodologies of health services planning and marketing are examined. Relevant primary and secondary sources of information are identified. Functions of board, management and planner/marketer are explored.

32.628 Ethics in Health (3-0)3 Examination of ethical theories and principles as they relate to the delivery of health services. Application to a variety of topics including allocation of scarce resources, accessibility of care, informed consent, human experimentation, life support systems, and health policy.

32.629 Long-term and Rehabilitation Services Management (3-0)3

32.633 Applied Studies in Health Promotion (3-0)3 Analysis of model health promotion programs designed to reduce morbidity and mortality due to major health problems such as heart disease, cancer and stroke. Derivation of principles useful in the development of new programs.

32.743 Thesis or
32.733 Project (3-0)3 Each student is required to complete a thesis or project under the supervision of a faculty member. The project is intended to integrate the concepts and skills learned in previous courses, should be original, and make a contribution to the field. Thesis must meet the requirements of the Graduate School and receive permission of the coordinator.

DEPARTMENT OF NURSING

Department Chair
May Futrell
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Graduate Coordinator
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Faculty
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Associate Professor; B.S., St. Anselm's College; M.S., Boston College; D.N.Sc., Boston University.
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Assistant Professor; B.S., Northeastern University; M.S., University of Lowell.
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Professor; B.S.N., St. Louis University; M.S.N., The Catholic University of America; Ph.D., Boston University.
Susan Houde
Assistant Professor; B.S., Lowell State College; M.S., University of Lowell; Ph.D., Brandeis University.
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Susan Reece
Associate Professor; B.S., Russell Sage College; M.S., Boston College; D.N.Sc., Boston University.
Janice Stecchi
Professor and Dean, College of Health Professions; B.S., Boston College; M.Ed. Salem State College; M.S., Ed.D., Boston University.
Joyce Wells
Assistant Professor; B.S.N., Fitchburg State College; M.S., University of Massachusetts Worcester.
Eileen Williamson
Associate Professor; B.S. Lowell State College; M.S., D.N.Sc., Boston University.

The philosophy of the Department of Nursing reflects beliefs regarding person, environment, health and nursing. People have unique, individual qualities and basic needs for respect, worth, and recognition of personal dignity. They have the right to make choices and establish goals which influence and are influenced by the environment. Health is a dynamic state of physiological, psychological, social and spiritual well-being. Nursing is a health care discipline which uses the nursing process to support individuals, families, groups and communities in the promotion of health throughout the life span.

Education is a self-actualizing, creative, lifetime endeavor involving values clarification, progressive systematic inquiry, critical analysis and judgment. The baccalaureate nursing program incorporates a liberal education with generalized preparation in professional nursing. The masters program is predicated upon a baccalaureate nursing education and prepares individuals as specialists.

MASTER OF SCIENCE DEGREE PROGRAM

Program of Study

The curriculum leading to a Master of Science degree with a major in Nursing emphasizes depth of knowledge and excellence in nursing in three areas of specialization: Adult Psychiatric and Mental Health Nursing, Gerontological Nursing and Family Health Nursing.

Purposes of the Master's Degree Program:

1. Provide advanced educational opportunities in nursing for baccalaureate prepared nurses.
2. Prepare leaders in Adult Psychi--atric/ Mental Health Nursing, Gerontological Nursing, and Family Health Nursing capable of improving nursing care through advanced practice.
3. Prepare leaders capable of planning and initiating change in the health care system.
4. Provide a foundation for doctoral education.

The graduate program is designed for a four-semester, two-calendar year schedule, although part-time study is possible. Within each major area of specialization all students are prepared with knowledge and skills necessary for leadership in a variety of settings. Methods of inquiry, research and scholarly techniques are

integral parts of the curriculum.

Program Objectives

The master's degree program prepares graduates who are able to:

1. demonstrate, through advanced nursing practice, a philosophy of nursing based on values that support the intrinsic worth and dignity of each individual,
2. actively engage in collaborative relationships with clients, peers and other health professionals to improve health care,
3. demonstrate advanced clinical expertise in a specialty,
4. evaluate own practice and promote professional and ethical standards of advanced professional practice in a specialty,
5. apply relevant theories and research findings in nursing practice to promote optimum wellness and to advance nursing,
6. initiate change for the improvement of health and health care services through consultation, collaboration, advocacy, and accountability,
7. evaluate changes and the change process for the improvement of health and health care services,
8. evaluate social, political, legal and ethical issues affecting nursing in an area of specialization and develop strategies for effective role implementation,
9. conduct scientific inquiry to contribute to knowledge relevant to nursing,
10. promote personal and professional development by continuing to acquire knowledge relevant to a specialized role.

Admission Requirements

Baccalaureate degree with a major in nursing from an accredited program

An undergraduate scholastic average of 3.0 or better

An introductory course in descriptive and inferential statistics

Official scores on the Graduate Record Examination

Licensed to practice nursing in the Commonwealth of Massachusetts

A pre-admission interview

Three letters of recommendation pertaining to academic ability and professional competency

Computer literacy

Goal statement

Official transcripts

Completed application and fees

Professional nursing experience

Additional Information

Students must carry malpractice liability insurance and CPR certification. Evidence of such much be provided. In addition, entering students are required to submit proof of the following to the University Health Service and Department of Nursing prior to registration:

1. immunization for measles, mumps, tetanus, diphtheria, and polio,
2. titers indicating immunity are acceptable for rubeola, rubella and mumps,
3. a negative mantoux (TB) test or Chest X-ray,
4. hepatitis vaccine series or evidence of positive HbsAg titer,
5. evidence of chicken pox, childhood history or titer,
6. the results of a physical examination using the official form from the University Health Service.

Degree Requirements

A minimum of 42 credits of course work will be required of all students. There are no formal language or comprehensive examination requirements. A research project or a thesis is required for graduation.

Part-Time Study

Students may be admitted for part-time study. Part-time students must meet the same admission requirements for graduate study as full-time students. Part-time students will meet with their assigned advisor and plan a schedule for their program of studies. This program of studies is planned by the end of the first semester so that placement in clinical nursing courses can be assured. Enrolling in courses as scheduled or changing courses requires approval from students' advisors. Students planning to complete the total program on a part-time basis may face delays if they decide to change to full-time status after admission.

Curriculum

Semester I		
33.600	Theoretical Foundations for Nursing	3
30.550	Human Development & Pathophysiology	3
33.552	Social, Cultural & Policy Issues in Health Care	3
33.651	Advanced Health Assessment	3
	TOTAL:	12
Semester II		
Specialty Theory I		4
Specialty Practicum I		3
33.553	Research Utilization	3
	TOTAL:	10
Semester III		
Specialty Theory II		4
Specialty Practicum II		3
Elective		3
	TOTAL:	10
Semester IV		
Specialty Theory and Practicum III		4
33.733 Project or		
33.743 Thesis		3
33.559 Advanced Pharmacology		3
	TOTAL:	10

Areas of Specialization

Gerontological Nursing

This specialty focuses on facilitating the health practices of older adults during the process of normal aging and identifying common health problems. Students develop advanced skills in communicating with older adults, health assessment, health teaching and nursing intervention and evaluation. Students are prepared as nurse practitioners and eligible to sit for the gerontological nurse practitioner certification exam.

33.610 Gerontological Nursing I
33.613 Gerontological Nursing Practicum I
33.611 Gerontological Nursing II
33.614 Gerontological Nursing Practicum II
33.612 Gerontological Nursing III

Family Health Nursing

This specialty focuses on facilitating the health practices of families during the process of normal development and identifying common health problems across the life span. Students develop advanced skills in communicating with families, health assessment, health teaching and nursing intervention and evaluation. Students are prepared as nurse practitioners and are eligible to sit for the family nurse practitioner certification exam.

33.660 Family Health Nursing I
33.663 Family Health Nursing Practicum I
33.661 Family Health Nursing II
33.664 Family Health Nursing Practicum II
33.662 Family Health Nursing III

Adult Psychiatric/Mental Health Nursing

In a health promotion, risk-prevention framework, the NP/CS blended program is designed to prepare advanced practice

psychiatric nurses to recognize and treat minor medical problems detected in comprehensive health assessments. While doing so, the program continues the clinical specialists tradition of preparing advanced practice nurses as competent therapists who care for individuals, families, and groups in a variety of settings. Students are prepared to sit for the Adult Psychiatric/Mental Health certification exam.

33.620 Adult Psychiatric/Mental Health Nursing I
33.623 Adult Psychiatric/Mental Health Nursing Practicum I
33.621 Adult Psychiatric/Mental Health Nursing II
33.624 Adult Psychiatric/Mental Health Nursing Practicum II
33.622 Adult Psychiatric/Mental Health Nursing III

The Ph.D. Program

The Doctor of Philosophy Program, a collaborative program of the University of Massachusetts Boston (UMB) and the University of Massachusetts Lowell (UML), provides study options in either health promotion or health care policy. Graduates with a health care policy focus will have gained the skills necessary to develop, maintain, and enhance health care delivery environments that foster equitable access to quality care. Graduates with a health promotion focus will advance knowledge on disease prevention and higher level wellness for individuals, families, and communities.

The goals of the program include: The development of knowledge in the areas of health promotion, disease prevention, and health care policy; the improvement of health care by preparing nurse scholars with expertise in the development, implementation, and evaluation of health promotion strategies and programs, and health care policy.

Admission Requirements

Students wishing to apply for admission to the program must submit a graduate admission application form. Applications must be received by April 1 at either the UMass Boston Graduate Admissions office(health care policy) or the UMass Lowell Graduate School (health promotion) for admission in the following fall semester. There are no spring semester admissions.
Additional requirements include:
1. A master's degree in nursing with a minimum G.P.A. of 3.3*;
2. A current Massachusetts R.N. license, or eligibility
3. A minimum of two years of pro-fessional nursing experience 4. Evidence of successful completion, within the past five years, of a course in multivariate statitics**;
5. An official report of scores on the general aptitude sections of the Graduate Record Exam (GRE)
6. Two offcial transcripts of all previous work (graduate and undergraduate)
7. A personal statement about the applicant's interest in the program
8. Three letters of recomendation including at least two from individuals who can assess the applicant's academic preparation for advanced graduate work

* Applicants who hold non-nursing master's degrees, who have established professional records in nursing, and who show potential for success in the Ph.D. program will be considered for admission on an individual basis.

** Applicants who do not meet this requirement will be considered for admission on an individual basis; if admitted, they will be expected to complete the course at the UMass Boston or UMass Lowell campus during their first semester in the program.

The Admissions Committee, composed of directors from each campus and senior core faculty who teach in the program, will interview finalists.

Degree Requirements

The program requires a total of 60 semester credits beyond the master's degree. These credits are distributed as follows:

Courses	Policy	Promotion
Core	9	9 (credits)
Concentration	15	12

Courses	Policy	Promotion
Research	24*	24*(credits)
Cognate	6	9
Elective	6	6

*Includes 12 dissertation credits

In addition to these requirements, health care policy students take a 14-week internship; health promotion students participate in on-going research apprenticeships.

Qualifying Examination

Students must pass a qualifying examination at the completion of the first thirty-six credits of required course work before enrolling in subsequent courses. Upon successful completion of the qualifying examination and all required course work, the student will be designated a candidate for the Ph.D. in Nursing.

Dissertation

Dissertation planning may be initiated in the first year, but formal work begins following successful completion of the qualifying examination. At this time a dissertation committee is formed to direct the student's research. In order to complete the requirements of candidacy, the student must submit a formal proposal for approval by the committee.

The dissertation requirement is designed to demonstrate that the student has acquired a substantial body of knowledge related to the selected field of study, has developed the ability to use appropriate data analysis methods, and has contributed to the advancement of nursing knowledge related to health care policy or health promotion.

Health Promotion Studies

Studies in health promotion, concentrated at UMass Lowell will prepare graduates to target behavorial and social factors as areas of intervention for health promotion and disease prevention at the individual, family, and community levels. Faculty and students will engage in research that develops, implements, and tests interventions focused on the reduction of the primary causes of morbidity and mortality. Graduates will be prepared for careers as researchers, clinicians, and educators who:
1. Create change in health care delivery-through the development, implementation of health promotion programs.
2. Extend the knowledge base of nursing in health promotion through research and theory development.
3. Contribute to health promotion policy development at local, regional, and national levels.
4. Develop and implement health promotion interventions to achieve high levels of wellness in target populations.
5. Assume leadership roles in the identification and resolution of health promotion needs across the lifespan.

Health Promotion Program of Studies

Core Courses	Credits
Science as a Way of Knowing	3
Research in Nursing and Health	

Promotion	3
Intervention Development in Health Promotion	3
TOTAL:	9
Research Courses	
Statistical Methods and Analysis	3
Research Methods and Experimental Design	6
Advanced Research Methods	3
Dissertation	12
TOTAL:	24
Concentration Courses	
Epidemiological Foundations of Health Promotion	3
Theoretical Foundations for Health Promotion	3
Advanced Research Seminar in Health Promotion	3
Research Apprenticeship in Health Promotion	3
TOTAL:	12
Cognate Courses	
Three courses selected to complement the individual student's academic focus	
TOTAL:	9
Elective Courses	6
Two methods courses which support the student's dissertation methodologies	
TOTAL:	6
Cumulative Total	60

COURSE DESCRIPTIONS

30.550 Human Development and Pathophysiology (3-0)3 Study of the biological aging process and its effect on the various physiological parameters of wellness. Defensive, compensatory, and adaptive responses to pathophysiologic processes are examined.

33.552 Social, Cultural and Policy Issues in Health Care (3-0)3 Grounded in nursing's holistic legacy, this course links health issues with other central domains of life: kinship, the political economy, policies of health and value systems of diverse groups. It draws on concepts from the humanities, social, behavioral, health, and policy sciences to critically examine factors affecting health (its promotion, preservation, breakdown, and restoration), and health seeking behaviors across the life course. It also examines how health behaviors and health outcomes are affected by context and how policies and structure orchestrate access to delivery of services. Nursing's pivotal role as a change agent to facilitate health promotion and appropriate healthcare delivery in an era of fiscal constraint and policy initiatives is analyzed.

33.553 Research Utilization (3-0)3 Course focuses on the critique and utilization of research findings, and the application of the research process. Researchable problems, the role of frameworks, sampling theory, research designs, and measurement strategies are emphasized.

33.559 Advanced Pharmacology (3-0)3 This course is designed to give the student the pharmacological principles necessary to understand the many factors involved in appropriate drug selection for the individual patient and those conditions commonly encountered in primary care practice. Emphasis will be placed on the decision making process in the prescriptive role.

33.600 Theoretical Foundations for Nursing (3-0)3 Course focuses on the analysis, critique, and application of theory as a basis for advanced practice nursing. Relationships among theories, research, and nursing practice are emphasized.

33.610 Gerontological Nursing I (4-0)4 Study of older adults and examination of commonly occurring health problems, family and community resources, legislative influences and ethical considerations. Emphasis placed on values, concepts and theories relative to the well-being of the aged individual.

33.611 Gerontological Nursing II (4-0)4 In-depth analysis of physiological and psychosocial factors relative to promoting, maintaining and restoring health of older adults.

33.612 Gerontological Nursing III (1-12)4 Synthesis of advanced knowledge and research serve as the basis for advanced gerontological nursing practice. Emphasis on implementation and evaluation of advanced practice strategies and the leadership role of the gerontological nurse practitioner.

33.613 Gerontological Nursing Practicum I (0-12)3 Development of leadership role in gerontological nursing. Focus is on comprehensive assessment, clinical decision making, identification of health problems and advanced nursing strategies to facilitate health promotion and maintenance.

33.614 Gerontological Nursing Practicum II (0-12)3 Practice in a leadership role in gerontological nursing. Emphasis on comprehensive assessment, advanced clinical decision making and management of acute and chronic stable conditions of the older adult. Opportunity to apply and evaluate concepts, theories and research findings is provided.

33.651 Advanced Health Assessment (2-4)3 The course focuses on the integration and application of theories from the social and biological sciences to develop advanced critical thinking and clinical judgment skills through comprehensive health assessment. Theories for health promotion and health maintenance and relevant research findings are utilized to evaluate health status and to identify health risk among individuals and groups. Age, gender, and culturally-related variations in health and health care, and attendant implications for advanced practice, are explored and discussed. Emphasis is placed on utilization of a systematic framework to develop and document and comprehensive health data base and problem-specific and goal-oriented plan care. The role of the advanced practice nurse as a provider of health care is introduced and discussed. Skills are developed and refined through laboratory practice and/or guided field experience.

33.660 Family Health Nursing I (4-0)4 Study of families with infants and children from multi-cultural systems, and examination of commonly occurring health problems. Emphasis placed on values, concepts and theories in terms of facilitating health promotion, maintenance and restoration.

33.661 Family Health Nursing II (4-0)4 Analysis of biological and psychosocial factors related to the health of childbearing, middle-aged and older adults within family systems and community suprasystems. Acute and chronic health problems are explored in depth.

33.662 Family Health Nursing III (1-12)4 Synthesis of advanced knowledge and research serve as the basis for advanced family nursing practice strategies. Emphasis on implementation and evaluation of advanced family practice strategies and the leadership role of the family health nurse practitioner.

33.663 Family Health Nursing Practicum I (0-12)3 Focus on development of leadership role in family health nursing. Emphasis placed on comprehensive assessment, clinical decision making, identification of health problems and advanced nursing strategies to facilitate health promotion and maintenance.

33.664 Family Health Nursing Practicum II (0-12)3 Practice in a leadership role in family health nursing. Emphasis on comprehensive assessment, advanced clinical decision making and management of acute and chronic health conditions. Opportunity to apply and evaluate concepts, theories and research findings are provided.

33.620 Adult Psychiatric-Mental Health Nursing I (4-0)4 In this course students examine commonly occurring physical and mental health problems among adults across the life span in multi-cultural populations. Resources, biopsychosociocultural, economic, legal/ethical, and policy issues are analyzed. Emphasis is placed on assessment, health promotion, prevention, intervention, and follow-up strategies for persons at risk for emotional distress/crisis and mental illness. Cost effective and safe delivery of therapeutic services in collaborative relationships with team members and clients are investigated.

33.621 Adult Psychiatric-Mental Health Nursing II (4-0)4 In this course, students focus on in-depth analysis of the psychosocial, biological, and multicultural factors influencing the mental and well-being of adults at risk for serious emotional/mental disability. Emphasis is on those adults presenting with acute and chronic emotional/mental

dysfunctions and the intersection between physical, psychosocial, and cultural facets of health and illness. The role of the advanced practice psychiatric-mental health nurse in health promotion, critical thinking, ethical decision making, appropriate pharmacologic therapies, mobilization of community resources for the emotionally/mentally disabled, and alternative nursing strategies are addressed.

33.622 Adult Psychiatric-Mental Health Nursing III (1-12)4 This course builds on Adult Psychiatric-Mental Health Nursing I and II. Learning opportunities encourage synthesis of knowledge and research utilization in advanced psychiatric-mental health nursing practice. Emphasis is on implementation and evaluation of preventive and psychotherapeutic strategies, drug therapeutics, policy issues, and the leadership role of the advanced practice psychiatric-mental health nurse.

33.623 Adult Psychiatric-Mental Health Nursing Practicum I (0-12)3
This course facilitates development of the advanced practice nursing role in adult psychiatric-mental health nursing in a primary care health setting. Focus is on comprehensive health assessments, advanced clinical crises and illness prevention, and the care of diverse persons across the life span with acute and episodic psychosocial problems and mental disabilities.

33.624 Adult Psychiatric-Mental Health Nursing Practicum II (0-12)3
This course focuses on advanced psychiatric-mental health nursing practice as a direct provider of selected services for diverse adults with acute and chronic mental health problems in a variety of settings. Application and evaluation of concepts, theories, psychotherapeutic strategies, and research findings are required, and interdisciplinary collaboration is emphasized.

33.743 Thesis (3-0)3 Course focus is on the application of the research process to a topic relevant to nursing practice and/or health outcomes. The student is expected to develop, implement, and report a study under the guidance of a designated faculty thesis committee.

33.733 Project (3-0)3
Course focus is on the practical utilization and application of nursing research. The student actively engages in one to two aspects of the research process under the guidance of a faculty mentor. The course product reflects a work effort which has practical implications for nursing practice.

COLLEGE OF MANAGEMENT

Dean
Kathryn M. Verreault
Associate Professor; B.S., University of Lowell; M.B.A., Ph.D., Texas A & M University.

Management Program Coordinator for M.B.A., M.M.S. and D. Eng.
Dr. Norma C. Powell
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Louis E. Yelle
Professor; B.S., Lowell Technological Institute; M.S., M.B.A, Northeastern University.

Eunsang Yoon
Associate Professor; B.A., Seoul National University; M.B.A., University of Georgia; Ph.D., Pennsylvania State University.

Accreditation

All programs offered by the College of Management are accredited by the American Assembly of Collegiate Schools of Business (AACSB).

MBA and MMS Programs

E-mail address:
MBA_MMS@uml.edu

THE MASTER OF BUSINESS ADMINISTRATION (M.B.A.) DEGREE PROGRAM

American business in the 1990's will be facing a very different internal and external environment from that which existed in previous decades. This environment will be characterized by rapid technological change, increased international competitiveness in manufacturing and other sectors, and a labor force which expects a higher quality of work life than did previous generations of employees. These changes directly affect the health and vitality of any region's economy.

The Master of Business Administration (MBA) program is designed to serve middle level professionals and others seeking management careers in business and industry. The program is designed to prepare students to manage effectively in rapidly changing regional, national, and global competitive environments.

The MBA program not only requires a thorough understanding of the traditional functional areas of business, but also provides a detailed, integrated examination of issues faced by contemporary managers. The unifying theme of industry analysis addresses the challenges posed by global competition, such as, accelerated change and complexity of technology, globalization of markets, increasing cultural diversity of human resources, ethical concerns, changing political processes, increasing role of governments in business, evolving organizational structures, and other similar issues.

With this philosophical framework as its driving force, the M.B.A. program at the University of Massachusetts Lowell prepares graduates to become leaders in a wide variety of commercial, industrial and governmental settings. Optional specializations are available in the fields of finance and marketing. The awarding of the M.B.A. degree signifies that the student has developed integrative skills in problem solving and decision making and can relate these skills to all functional areas of business. The development of this expertise entails an examination and application of advanced analytical tools.

Graduate Assistantships

Teaching and research assistantships are available to limited qualified full-time M.B.A. students in the College of Management (C.O.M.). These awards provide students with a stipend for the academic year. The primary purpose of these awards is to provide promising graduate students with financial assistance to offset the costs of full time graduate study. They also benefit students by providing an opportunity to build knowledge and skill in various aspects of business administration by working closely with members of the C.O.M. faculty.

Computer Facilities

Full-time and part-time M.B.A. students have access to extensive computer facilities both inside and outside of the College. Within the College, students may utilize numerous IBM-compatible microcomputers located in the C.O.M. microcomputer laboratory. Use of this equipment, as part of course work or in conducting research, familiarizes students with computer technology in general, and provides them with specific micro and main-frame computer skills that are vital for success in today's business world.

Entrance Requirements

Admission to the M.B.A. program is open to students who have earned the baccalaureate degree. An aptitude for management decision-making and demonstrated academic ability are the most important qualifications for admissions. It is also required that applicants have an adequate mathematics background. Applicants should submit, along with their Graduate School application, an official transcript of grades from their undergraduate institution(s), an official Graduate Management Admission Test (G.M.A.T.) score (the Graduate Record Examination is not an acceptable alternative), three letters of recommendation, (letters of recommendation from work-related sources are preferred), a resume, and a one-page typewritten statement of academic and career goals. Students for whom English is not their national language must also submit an official score report for the Test of English as a Foreign Language (TOEFL).

Part-time and Full-time Study

M.B.A. students may attend either full-time or part-time. Most courses, at present, meet during the evening hours beginning at 6:00 p.m. Courses are offered in the fall and spring semesters. A minimum full-time course load is considered to be 9 credits. Full-time students usually complete their degree requirements in two years. Part-time students

must complete their degree requirements within five years.

Admission to M.B.A. Courses

M.B.A. advanced core courses are open only to College of Management graduate students who are fully-matriculated degree candidates.

Residency Requirement

To be recommended for the M.B.A. degree, students are required to complete a minimum of ten courses (30 credits) beyond the Foundations Core in the M.B.A. program at the University of Massachusetts Lowell. Only under special circumstances, and with prior approval, are students permitted to complete courses at other institutions.

Curriculum Requirements

The M.B.A. program consists of twelve hours of prerequisite foundation core courses which may be waived through previous undergraduate work, and thirty credit hours (10 courses) of advanced courses and electives, for a total of 42 credit hours.

Pre-requisites:
65.501 Economics
65.502 Quantitative Foundations

Foundations Core Courses (6 courses-12 credits):
60.501 Financial Accounting
61.501 Business Financial Analysis
62.501 Marketing Fundamentals
63.501 Operations Management
66.501 Behavioral Foundations of Organizations
66.511 Global Enterprise and Competition

Guidelines for Graduate Equivalency Credit of Foundations Core Courses

The maximum number of courses that can be given equivalency credit is 12 credits. A student accepted to the University of Massachusetts Lowell MBA program may request equivalency credit for any of the core courses listed below. These courses may be credited with exemption (meaning a replacement course is not required) if the equivalent undergraduate course work was completed with a grade of "B" or better within the past five years. For courses taken more than five years ago with a grade of "B" or better, a student may take a written exam to demonstrate proficiency. Additionally, up to two elective courses for 6 credits can be transferred in from an AACSB-accredited MBA program only.

Equivalent Undergraduate

MBA Core Courses (2 credits each)
60.501 Financial Accounting (1 semester)
61.501 Business Financial Analysis (1 semester)
62.501 Marketing Fundamentals (1 semester)
63.501 Operations Management (1 semester)
66.501 Behavioral Foundations of Organizations (1 semester)
66.511 Global Enterprise and Competition

Required Advanced Core Courses (7 courses-21 credits):
60.601 Accounting Information for Management Decisions
61.601 Corporate Finance
62.601 Analysis of Customers and Markets
63.601 Management Information Systems
64.601 Operations Management
66.601 Managing Organization Design and Change
66.691 Strategy Formulation and Implementation

Electives or Concentrations

(courses-9 credits):

Students may choose to concentrate in a particular field by taking 3 electives or 2 electives and a field project in a specific area of study in one department or a combination of departments. Alternatively, students may take three unrelated electives and opt for a non-concentration degree.

University of Massachusetts Lowell has two six-week summer sessions. The first summer session begins approximately the third week in May and ends the last week in June. The second session begins after the fourth of July week and runs through the third week in August. Only elective courses are offered in summer sessions. To take electives, students must have completed the foundation core and be matriculated.

COURSE DESCRIPTIONS

60.501 Financial Accounting (3-0)2
Is an introduction to financial accounting within the context of business transactions and business decisions. This course is a broad introduction to using accounting information from the user's perspective with little emphasis on traditional debits, credits, journal entries and ledgers. Emphasis is placed on preparing and understanding financial statements.

60.601 Accounting Information for Management Decisions (3-0)3
Pre-Requisite: Student must be matriculated and must have completed foundation core courses. Focuses on the manager's view as opposed to the accountant's view of the decision process and related quantitative and non-quantitative information needs. The course material examines accounting information that will achieve faster, better, and cheaper operations. New strategic cost management models, such as ABC and target costing, are explored and contrasted with traditional cost approaches.

60.677 Independent Study in Accounting (3-0)3 Prerequisite: Completion of Foundations Core and permission of the instructor.

60.730 Federal Income Taxes (3-0)3
Prerequisite: Completion of Foundations Core. The basic rules and regulations of the Internal Revenue Code as it affects individuals and business firms. The role of taxation in the business decision making process. The tax effects of alternative types of organization, depreciation and inventory methods, mergers and acquisitions, and other important topics.

61.501 Business Financial Analysis (3-0)2
Prerequisite: 60.501. Introduces students to the finance function in a firm. Students are exposed to a variety of analytical techniques and to theory applied to financial decision making. Study will include effects of major financial decisions such as investment, financing and dividends on the value of a firm, in the light of their risk-return relationship under the assumption that the maximization of shareholder wealth is the goal of management.

61.601 Corporate Finance (3-0)3
Relates working capital strategy, capital investment analysis, long-term financing, and capital structure decisions in a risk-return framework to the dynamics of the firm and the market in which it operates.

61.677 Independent Study in Finance (3-0)3 Prerequisite: Completion of Foundations Core and permission of instructor.

61.688 Current Topics in Finance (3-0)3
Prerequisite: 61.601. Selected topics having current and future impact in the field of finance.

61.735 Portfolio Investment and Security Analysis (3-0)3 Prerequisite: Completion of Foundations Core. Development of investment theory as applicable to portfolio management and securities selection.

61.760 International Financial Management (3-0)3 Prerequisite: Completion of Foundations Core.
The international dimension of the finance function of the firm. Financial constraints of the international environment and their effect on the standard concepts of financial manage-

ment. The techniques of adapting risk analysis to the international situation. Study of international currency flows, monetary systems, forward cover and international banking policies.

62.501 Marketing Fundamentals (3-0)2 Describes how marketing strategies and plans of a competitive enterprise are formulated, implemented, and adjusted over time. Behavioral and quantitative aspects are covered, as well as analysis of the environmental forces affecting marketing decisions.

62.601 Analysis of Customers and Markets (3-0)3 Prerequisite: Student must be matriculated and have finished foundation core. Pursues the development of comprehensive and integrated marketing plans using industry/competitor analysis, market value chains, and forecasting. An emphasis is given to business-to-business marketing situations which require an in-depth analysis of the firms' complex organizational behavior and evolving buyer-seller relationship.

62.660 Marketing Communications (3-0)3 Prerequisite:Completion of Foundations Core. The social and economic role of promotion, and the historical development of mass media and advertising. Advertising research, creation and production as a tool of marketing management.

62.677 Independent Study in Marketing (3-0)3 Prerequisites: Completion of Foundations Core and permission of instructor.

62.688 Current Topics in Marketing (3-0)3 Prerequisite: Completion of Foundation Core. Selected topics having current and future impact in the field of marketing.

62.710 Marketing Research (3-0)3 Prerequisite:Completion of Foundations Core. The formulation, execution, and interpretation of marketing research projects, within the broader context of a marketing intelligence system. Research design, data collection methods, and sampling theory.

62.780 Marketing Analysis and Planning (3-0)3 Prerequisites: Completion of Foundation Core. Managerial decision-making aspects of marketing including design and use of models, marketing's organizational relationships, utilization of market research data, and performance evaluation and control through marketing audits.

63.501 Operations Fundamentals (3-0)2 Provides students with an introduction to operations management and operations analysis. The latter furnishes the student with a set of quantitative tools which are useful in designing and operating the former. These techniques are also generally applicable to other functional areas/courses within the MBA Program.

63.601 Management Information Systems (3-0)3 Pre-requisite: Student must be matriculated and have finished foundation core. Examines computer technologies, database management, and data communications as vehicle to improve and/or restructure business processes and decision making effectiveness to create competitive advantage.

63.607 Independent Study in Management Information Systems (3-0)3 Prerequisite: Completion of Foundations Core and permission of the instructor.

63.651 Integrated Logistics (3-0)3 Prerequisites: 64.601 or 63.710. This course focuses on the process of transforming an order into a delivered product at the right time, in the right condition, and at the right price. The course introduces logistics activities such as procurement, inventory, distribution, transportation and warehousing, customer service, and order processing, and approaches for managing material and information flows among the activities. Issues such as total logistics costs, logistics re-engineering, supply chain inventory strategies, logistical information strategies, performance measurement, coordination of supply chain activities, and inter-company relationships are addressed.

63.677 Independent Study in Operations Management (3-0)3 Prerequisite: Completion of Foundations Core and permission of instructor.

63.688 Current Topics in Management Information Systems (3-0)3 Prerequisite: Completion of Foundations Core. Selected topics having current and future impact on the field of management information systems.

63.705 Advanced Management Information Systems (3-0)3 Prerequisite: Foundations Core or permission of instructor. The study of two key computer technologies: data base management and data communications. These are applied to various business computer systems such as distributed processing systems, on-line real-time systems, office automation, factory automation, and decision support systems. Other topics include control and auditing, documentation standards, as well as legal and social aspects of data processing.

63.765 Operations Planning and Control (3-0)3 Prerequisite: Completion of Foundations Core. An examination of the complex decisions faced by the operations manager. Topics include the design of forecasting, production planning, inventory control, and quality control systems, and how each of these systems is integrated into the firm as a whole. Cases and readings used extensively.

63.775 The Practice of Operations Management (3-0)3 Prerequisite: Completion of Foundation Core. An application of the student's quantitative skills to identify, model and solve actual operational problems in local business firms. Problem areas addressed include product mix decisions, facility layout and location, transportation and distribution, carrier selection, and inventory stocking policies. Modeling techniques used include linear programming, decision theory and simulation.

64.601 Operations Management (3-0)3 Prerequisite: Student must be matriculated and have finished foundation core. Examines the strategic and tactical operations processes of manufacturing and service firms that foster global competitiveness. This course focuses on traditional and newer approaches including just-in-time, total quality management, MRP, flexible manufacturing systems, and capacity management that lead to an integrated operations strategy. Cost reductions, flexibility, and market responsiveness are also considered.

64.621 Decision Methods and Techniques (3-0)3 Prerequisite: Student must be matriculated and have finished foundation core. This course encompasses the areas of optimization models, methods, and methodology of field research. Data treatment and research design focus on advanced statistical and analytical techniques. The course material examines the significance of the models and their capabilities for problem-solving. Field projects involving data collection and analysis place an additional emphasis on computational experience and selection of applications software to assist the researcher in achieving research objectives.

64.631 Financial Policy and Strategy (3-0)3 Prerequisite: Student must be matriculated and have finished foundation core. Financial Policy and Strategy concentrates on three specific areas: Working Capital Strategy, Capital Investment Analysis (including Abandonment Analysis), and Capital Structure Strategy. Working Capital Strategy (WCS) is an important determinant of corporate profitability and ability to fund immediate growth and react to changing market opportunities and threats. Capital Project Investment Analysis focuses on methodologies used to evaluate prospective and ongoing investment projects. Particular attention is paid to the specific problems of international capital flows and the impact of trading blocks on capital formation and capital movement. Capital Structure Strategy is an examination of the firm's capital structure and how it relates to the dynamics of the markets in which the firm operates.

66.501 Organizational Behavior (3-0)2 Introduces students to management and organizational behavior. Its general purpose is to study and understand the behavior of individuals and groups in organizations. It is directed toward behavioral action components and emphasizes the close relationship between the study of organizational behavior and the practice of management.

66.511 Global Enterprise and Competition (3-0)2 Prerequisites:To be taken as last course in foundation core. Is an integrated investigation of global competitive isues to help students understand the processes of organization and technological innovation which permit businesses to achieve competitive advantages in a global environment. This course also deals with the nature and techniques of indus-

try analysis necessary to the formulation of effective global strategy for the firm.

66.601 Managing Organization Design and Change (3-0)3 Prerequisite: Student must be matriculated and have finished foundation core. Examines how business enterprises are designed, managed and changed to operate efficiently and perform effectively within their competitive environments. It critically examines organizations that vary in terms of such characteristics as size, complexity, goals, and technology as they operate under different circumstances and at various stages of their life cycles. The role and impact of individual managers receive particular attention.

66.677 Independent Study in Management (3-0)3 Prerequisite: Completion of Foundations Core and permission of instructor.

66.688 Current Topics In Management (3-0)3 Prerequisite: Completion of Foundations Core. Selected topics having current and future impact in the field of management.

66.691 Strategy Formulation, Implementation and Control I (3-0)3 Prerequisite: Student must be matriculated and have finished foundation and advanced courses. Reviews strategies for positioning a firm within its competitive environment. Fundamental concepts in strategic management; role of the CEO, levels and components of strategy, competitive analysis, and formulation and implementation of strategy are explored.

66.705 Human Resources Management (3-0)3 Prerequisite: Completion of Foundations Core. Recruitment, selection, training, human resource planning, compensation management, equal employment opportunity, performance evaluation, management development, discipline, and employee health and safety. The role of the human resource executive in corporate management and strategic planning.

66.730 Work System Design (3-0)3 Prerequisite: Completion of Foundations Core Focus is on the design of work at the operations level. Reviews the range of work arrangements available globally, analyzes the advantages and disadvantages of each, presents principles of task and work design, and develops a realistic understanding of the role of unions in shaping tasks in unionized U.S. work environments. Strong emphasis on linking concepts learned in class with "real-world" cases.

66.735 Employee/Employer Relations (3-0)3 Prerequisite: Student must be matriculated and have finished foundation core. A study of public policy toward labor-management relationships. Regulation by the National Labor Relations Board, collective bargaining, arbitration, civil rights, and the application of anti-trust law to unions.

66.760 Organization Design and Change (3-0)3 Prerequisite: Completion of Foundations Core. How general managers can create, rearrange and improve organization structures and sub-units. Identifies design and change methods for more efficiently controlling and directing behavior toward the achievement of corporate goals and strategies.

66.770 Leadership (3-0)3 Prerequisite: Completion of Foundations Core. Focus is on the macro aspects of leadership. Reviews various leadership theories, its basic roots in Western and Eastern philosophies, and its manifestation in traditional hierarchical organizations, entrepreneurial operations and participative structures. Examination of personal leadership strategies for individual and organizational effectiveness in globally competitive environments.

CERTIFICATE:

The College of Management also offers a Certificate in the Management Foundations of Business (MGFB) which consists of the prerequisites Micro Economics and Statistics, as well as the 6 Foundation Core courses:

60.501 Financial Accounting
61.501 Business Financial Analysis
62.501 Marketing Fundamentals
63.501 Operations Fundamentals
66.501 Organizational Behavior
66.511 Global Enterprise and Competition

A GMAT exam is not required for Certificate Program. An undergraduate transcript must be supplied by student when applying.

THE MASTER OF MANAGEMENT SCIENCE (MMS) IN MANUFACTURING DEGREE PROGRAM

Program Mission

Over the past decade, the United States has become decreasingly competitive as other nations have developed their capacity to efficiently design, produce and distribute high quality products worldwide. This development has lead to a decrease in U.S. economic health, as manifested in high foreign trade deficits, substantial decline in the manufacturing sector of the economy, and an increase in industrial unemployment.

Decreased global competitiveness in manufacturing has in part influenced, and been influenced by, declines at the state and regional levels, such as in Massachusetts and New England, where manufacturing has traditionally been strong. Therefore, to facilitate economic development, and regain U.S. economic leadership internationally, the manufacturing sector of state and regional economies must be revitalized.

The mission of the College of Management (C.O.M.) is to address these issues by offering high quality academic programs that prepare managers to perform effectively in the industrial sector of the economy. The Master of Management Science in Manufacturing (M.M.S.) is intended to achieve this goal.

The purpose of the M.M.S. is to produce graduates with focused and integrated management and engineering skills that foster more effective leadership in manufacturing settings -- leadership that will promote the development of low cost, high quality, and innovative products and processes. To achieve this goal, the program has eight specific educational objectives.

Program Objectives

These are to produce graduates who:

- Can understand and creatively apply current knowledge from the management and engineering disciplines applicable in manufacturing settings that will decrease production costs, improve product quality and create new products that are quick to market;
- Can identify existing barriers to high quality, cost-effective processes, and determine why these barriers exist;
- Can understand and apply current management and engineering tools, techniques and strategies developed in the U.S. and abroad to overcome these barriers;
- Are able to clearly differentiate between, and effectively link, the management and engineering aspects of product- and process-related issues in the workplace;
- Understand the role of the manufacturing function in the firm and its systemic relationship to the other functional areas of business;
- Can develop and effectively articulate new strategic manufacturing options that both support, and potentially direct, the firm's overall mission and objectives;
- Have a broad conceptual understanding of the role of manufacturing as an activity that can both foster or hinder economic competitiveness in industrial societies; and
- Recognize that managerial decision making in manufacturing settings should be based on a sound ethical foundation, at the center of which is a concern for employee health and safety, the quality of work life, and the integrity of the physical environment.

Course of Study

The program achieves these objectives by offering an integrated series of eleven 3-credit Management and Engineering courses. Eight of these courses are offered by the College of Management and three by the College of Engineering. The following courses comprise the program:

College of Management (24 credits)

- Managing for Competitiveness I (66.710)
- Quantitative Methods for Decision Evaluation (61.802)
- Design and Control of Manufacturing Systems (63.710)
- Market and Customer Values (62.804)
- Manufacturing Strategy (63.720)
- 3 courses designed by the Graduate Programs Committee

College of Engineering (9 credits)

- 3 courses designed by the College of Engineering faculty

Curriculum Structure

With respect to some courses, the sequence is determined by prerequisite considerations. In no cases may an advanced course be taken until all prerequisites are satisfied. In most cases, courses meet in the evening beginning at 6:00 p.m.

Admission Requirements

Students considered for admission to the M.M.S. program must have earned either an undergraduate or graduate degree in (a) an engineering discipline or (b) a scientific discipline that included a strong mathematics component. This background should include at least three courses in Calculus; Mathematical Statistics or Probability; and two courses in Physics.

Applicants with degrees in Industrial Management or Engineering Technology are evaluated on a case-by-case basis according to criteria established by the College of Management. Work experience in a manufacturing setting is preferable, but not required.

Admission Procedures

To apply for admission, students must submit: (1) an application form; (2) official transcripts from all prior degree programs completed; (3) a score on the Graduate Management Admissions Test (G.M.A.T.) or Graduate Record Examination (G.R.E.); (4) three letters of recommendation from persons in a position to evaluate their potential for success in a Masters program in manufacturing management; (5) a current resume; and (6) a prose statement describing why they wish to be admitted to the M.M.S. program. This statement should include an assessment of the applicant's professional goals and how earning a M.M.S. degree will facilitate goal achievement. In addition, a score on the Test of English as a Foreign Language examination (T.O.E.F.L.) must be submitted if the applicant is a citizen of a non-English speaking country and has never earned an academic degree in the United States.

Admission to M.M.S. Courses

In general, students may not enroll in M.M.S. courses unless they are matriculated students in the program. Matriculated status is achieved either through non-conditional admission to the program or, in a small number of cases, through admission with conditions. Matriculation with conditions requires a student to meet specific academic performance goals by the end of the first semester.

Exceptions to this policy may be made by the M.M.S. Program Director on a case-by-case basis for (1) students matriculating in the U/Mass Lowell M.B.A. program; (2) students matriculating in graduate programs offered by U/Mass Lowell's College of Engineering; (3) qualified individuals admitted to the College of Management as Special Students who are enrolled in graduate programs at other institutions; and (4) other students who satisfy course prerequisites and standards established by the M.M.S. Program Director in consultation with the M.M.S. Program Committee.

Transfer Credit

A maximum of six (6) transfer credits (2 courses) may be accepted from another institution toward M.M.S. program requirements. To transfer, the student must have earned a grade of 'B' or better in a course that: (a) closely corresponds in content to a required M.M.S. course; and (b) was taken at an A.B.E.T. or A.A.C.S.B.-accredited institution, for a course in an Engineering or Management discipline, respectively. If transfer credit is granted, it will have the effect of reducing the number of U/MASS Lowell courses required for graduation.

Full-time and Part-time Study

Students are admitted to the program on either a full-time or part-time basis. The full-time and part-time options differ only in the number of credits taken per semester. (9 credit hours is considered to be full-time) All courses are taught by full-time doctorally qualified faculty.

Academic Standards and Graduation Requirements

In general, all rules and policies of the UMass Lowell Graduate School apply to students enrolled in the M.M.S. Program. Additional rules and policies regarding academic standards and other matters are developed by the M.M.S. Program Director and Program Committee as appropriate, and shall be consistent with rules and policies of the Graduate School and University.

To be recommended for graduation, students must earn an overall grade point average of 3.0 or better (a 'B' average). With the exception of transfer credit, all course work must be completed at the University of Massachusetts Lowell. Only under special circumstances, and with prior approval, may M.M.S. courses be taken at other institutions.

Graduate Assistantships

Graduate Assistantships are available to qualified full-time students, and are awarded on an annual basis. They include a stipend from which the student pays all university tuition and fees. The primary purpose of an Assistantship is to provide promising graduate students with financial assistance to offset the costs of full-time graduate study. It also provides students with an opportunity to build professional knowledge and skills by working closely with members of the College of Management faculty in the conduct of their teaching and research.

To be eligible, an applicant must be admitted to the program as a matriculated student without conditions. Assistantships will be awarded competitively based on the applicant's academic record and prior work experience. As part of this assessment, consideration will be given to the potential contribution an applicant can make to the program and College in the areas of instructional assistance and research.

Computer Facilities

Full-time and part-time M.M.S. students have access to extensive computer facilities both

inside and outside of the College of Management. Within the College, students may utilize IBM-compatible computers located in the C.O.M. microcomputer laboratory.

COURSE DESCRIPTIONS

63.710 Design and Control of Manufacturing Systems (3-0)3 This course examines key tactical decisions that manufacturing firms must address in operating a competitive, integrated production system. Students learn to assess alternative ways of processing, and ways to manage, production systems that will help achieve company goals. Topics include manufacturing technology and process analysis; production planning and material control; quality management and control; process improvement; and cross-functional integration. Students focus on management issues associated with a variety of processing environments, and on appropriate settings for the use of approaches such as Flexible Manufacturing Systems, Material Requirements Planning I and II, Just-in-time Production, and Quality Control. The course draws on readings, cases, and analytical models.

63.720 Manufacturing Strategy (3-0)3 This course focuses on the role of manufacturing strategy as part of a corporation's overall mission. The link between manufacturing strategy and business strategy is constantly stressed. It demonstrates how a firm's manufacturing unit can be either a competitive weapon or a corporate millstone. Using cases and readings, students learn how the development of unique manufacturing strengths can directly shape a firm's broader strategic posture. Topics covered include a variety of strategic design and policy considerations including: the choice of organizing by product or process; time-based competition; manufacturing technology policy; productivity measurement and enhancement programs; the use of quality as a strategic weapon; manufacturing strategy over time; and the globalization of the manufacturing process.
Prerequisite: 63.710, 66.710, 61.802, 62.804

66.710 Managing for Competitiveness (3-0)3 To manage manufacturing organizations, and assure continual improvement in company products and processes, managers must understand, and be prepared to modify, how the firm operates in terms of structure, policies, reward systems, work and management processes, and core values. This requires considerable skill in (a) correctly distinguishing between the technical and managerial aspects of company performance and (b) developing strategic and tactical approaches that, when implemented, lead to necessary change. This course addresses these managerial issues. Emphasis is placed on designing the proper alignment between company goals, structure and external environment; developing managerial skills in communicating, and motivating; applying quality management strategies; and facilitating planned organizational change.

61.802 Quantitative Methods for Decision Evaluation (3-0)3 Quantitative analysis for evaluating new product introduction and new technology adoption are emphasized. Students are introduced to the fundamentals of accounting and financial analysis, followed by more advanced topics relevant to decision making in manufacturing settings. Topics include activity based costing, break-even analysis, capital budgeting, risk measurement and the required rate of return. The course will also explore the differences between information developed for financial reporting and the information required to make managerial decisions in a dynamic environment.

62.804 Market and Customer Values (3-0)3 Prerequisite: Doctoral student standing. For a business to survive it must correctly conceptualize, comprehend, communicate, and deliver value to it's customers and markets. This course is designed to provide students with an understanding of the customer and how the complex decision to purchase is reached. The focus is how to assess the needs of the market and particular customers; the considerations that must be balanced in choosing what customers and markets to serve; designing the business and product/service offering; and using various selling and communication alternatives to reach the customer or market.

22.571 Concurrent Engineering (3-0)3 This course familiarizes students with the concepts, techniques and tools of concurrent engineering and its role in product design and development. Through a case study examination of relevant analytical tools, it analyses and applies the methodologies used by world class companies to guide, in the most timely fashion, the development and design of high quality, low cost products. Topics include strategic and process issues in the creation of new products, organizational aspects of multidisciplinary design teams, concurrent engineering project management, structural methodologies for identifying customer requirements and process behavior, setting appropriate quality and design efficiency levels, and new product development methodology, design selection and optimization.

22.573 Manufacturing Systems (3-0)3 This course concentrates on the design and evaluation of manufacturing systems. It includes the design of experiments, robust design, performance measures, statistical process control, stochastic process models, simulation models and optimization methods.

22.579 Robotics (3-0)3 This course addresses the theory and design of robotics technology as a component of the manufacturing process. Topics covered include movement and imaging under the homogeneous representation; robotic joints; robot classification and analysis; inverse kinematic solutions; parametric description of curves; trajectory planning; and dynamics and control.

22.624 Theory and Practice of Engineering Design (3-0)3 The Engineering Design Process (EDP) is examined as the integral component of the Product Realization Process. The process includes need identification, the design brief, and identification of design objectives and problems. EDP is viewed as an iterative modeling of the developing system or product, as well as its subsystems and components. Also included in the course are the role of laboratory experiments, pilot system/sub-system testing, EDP structural models, and Design for 'X' (manufacturing, quality, assembly, reliability, etc.). Economic and other non-engineering issues in design are also discussed. Students plan and develop design projects.

Business Management Curriculum for the Doctor of Engineering (D.Eng.) Program

American competitiveness in world markets requires both technical innovation and the business skills to bring these innovations to market profitability. The management component of the University of Massachusetts Lowell's Doctor of Engineering Program is designed to complement the technical training of the engineer with knowledge and skills in team management, financial decision making under market uncertainty, sensitivity to market needs, leading edge manufacturing techniques, and winning business strategies.

The philosophy and goals of the management component of the Doctor of Engineering program is to develop a person who can effectively extend the limits of technology both as a member of a professional work team and as a member of a global society. Today's professionals will find that, over their work lives, they will hold several different types of positions in fields using their professional education — in the business world, in academia, or in other endeavors. Regardless of the environment, a core of "management" skills will be required for success. The professional must be able to understand the external and internal work environment, understand the criteria that form the basis for decisions, and understand and evaluate the implications of those decisions.

To achieve these goals, the College of Management Science has established the following objectives for the management curriculum of the Doctor of Engineering program:

1. Overview of Management and Organizations Proficient with management concepts and functions
-Skills to function effectively in complex organizations
-Ability to understand and initiate change in both organizations
-Prepared to champion, as entrepreneur, new ideas or products
2. Appreciation of the Environment of Business
-Understanding of the business and technological implications of the global concept
-Understanding of the social/legal/ethical interactions of business and technology in the institutional and social environment
3. Development of Evaluation/Planning/ Implementation Skills
-Understanding technological innovation/diffusion processes and implications for resource allocation and action programs
-Capability to measure profit potential implications of new technology and products
-Ability to evaluate strategic business implications of technological decisions
-Capability to evaluate the profit and market implications of alternative policy and strategy options

In summary, the candidate should have the capabilities to understand and make key business decisions, develop, implement, and alter strategic initiatives, and effectively serve as a leader in an organizational setting.

The management curriculum for the Doctor of Engineering program is a free-standing, self-contained package of courses. These courses do not assume a previous knowledge of business or management subjects by the engineering student.

The management component of the doctor of engineering program consists of three College of Management courses from the M.M.S program.

Certificate in Commercialization of Science and Technology: LCST

64.801 Structure and Dynamics of Private Enterprise (3-0)3 This course provides the student with an understanding of the fundamentals of business in today's globally competitive environment. Instruction focuses the students' attention on: the forces affecting private enterprises; the functional disciplines developed to respond to these forces; techniques for analyzing the competitive position of enterprises, and the principles for coordinating and motivating enterprise employees. Prerequisite: Doctoral Standing

61.802 Quantitative Methods for Decision Evaluation (3-0)3 Quantitative analysis for evaluating new product introduction and new technology adoption are emphasized. Students are introduced to the fundamentals of accounting and financial analysis, followed by more advanced topics relevant to decision making in manufacturing settings. Topics include activity based costing, break-even analysis, capital budgeting, risk measurement and the required rate of return. The course will also explore the differences between information developed for financial reporting and the information required to make managerial decisions in a dynamic environment. Prerequisite: 64.801

64.803 Manufacturing Strategy (3-0)3 Students are exposed to manufacturing strategy as a weapon in the competitive arsenal. The course reviews competitive changes in manufacturing...from craft to lean manufacturing; explores modern manufacturing 'tools' and their competitive use; adds a market perspective to total quality control; examine the manufacturing and market implications just-in-time systems, as well as explore the implications of linking product and process design. Prerequisite: 61.802

62.804 Market and Customer Values (3-0)3 For a business to survive it must correctly conceptualize, comprehend, communicate, and deliver value to it's customers and markets. This course is designed to provide students with an understanding of the customer and how the complex decision to purchase is reached. The focus is how to assess the needs of the market and particular customers; the considerations that must be balanced in choosing what customers and markets to serve; designing the business and product/service offering; and using various selling and communication alternatives to reach the customer or market.

64.805 Competitive Decision Making (3-0)3 The aim of this course is to have the student understand the complex decision issues for developing sustainable competitive advantage. The course focuses on a) environmental forces (increased global competition, shortened product life cycle, and differences in management style); b) boundary spanning issues interfaces; and c) managing for competitive advantage (strategic thinking, participative management, quality and productivity). Prerequisite: 64.803 and 62.804

CERTIFICATES

The College of Management offers a Graduate Certificate in Leadership in Commercialization of Science and Technology.

In today's highly competitive and resource constrained environment, success in the marketplace is more challenging than ever. This challenge requires scientists and engineers with the capabilities to understand and make key business decisions; develop, implement, and alter strategic initiatives; and effectively serve as leaders in an organizational setting. The certificate will provide training in the areas listed below:

Required Courses:

61.802 Quantitative Methods for Decision Evaluation
62.804 Market and Customer Values
63.710 Design and Control of Manufacturing Systems
66.710 Managing for Competitiveness

All the above courses can be applied to the Master of Management Science (M.M.S.) Degree in the College of Management.

The College of Management also offers a Graduate Certificate in Software Project Management & Entrepreneurship

This certificate consists of courses from both the Computer Science Department and the College of Management. It is designed for students who hold a baccalaureate degree and are interested in developing and managing large scale software projects.

Required Courses:

91.521 A Discipline for Software Engineering
91.522 Object Oriented Analysis and Design
91.589 Creating the High Tech Software Driven Venture

Plus One Approved Elective

All courses for the certificate may be used toward a graduate degree in the Computer Science Department subject to the approval of the graduate coordinator. The management courses can be used toward the Master of Management Science in Manufacturing. (M.M.S.)

For semester schedules, curriculum changes, and new courses, visit the College of Management's web site at: http://www.uml.edu/College/Management/grad.index.html.

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3 Costello Gym
4 Cumnock Hall
5 Bourgeois Hall
6 Eames Hal
7 Engineering building
8 Falmouth Hall
9 Health Servicesl
10 Kitson Hall
11 Lydon Library
12 Olney Hall
13 Olsen hall
14 Pasteur Hall
15 Pinanski Hall
16 Power Plant/Garage
17 Riverside Lot
18 Southwick Hall
19 Smith hall
20 Baseball/Football Stadium
21 Donahue Hall
22 Fox Hall
23 Leitch Hall
24 Recreation Center (Planned)
25 Riverwalk
26 Tsongus Arena
27 Institute for Plastics Innovation
28 Mogan Cultural Center
29 Tsongus Ind. History Center
30 Wannalancit
31 Allen House
32 Coburn Hall
33 Concordia Hall
34 Dugan Hall
35 Durgin Hall
36 Lovejoy Lot
37 Mahoney Hall
38 McGauvran Student Union
39 O'Leary Library
40 Power plant (South)
41 Riverview Lot
42 Sheehy Hall
43 South Side Cafe/Dining Hall
44 Weed Hall
45 Demonstration School
46 Gazebo
47 Gould Hall
48 Read Hall
49 The Residence
50 Richardson Hall
51 Upham Hall
52 Bigelow Hall

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